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STANDARD ELECTRONIC MODULE RADAR COST ANALYSIS.(U)
JUL 77 R HOEFLE, R ARCHBALD, R LIPELES F33615-76-C-1306
UNCLASSIFIED 1266-R-0007 AFAL-TR-77-26 NL

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STANDARD ELECTRONIC MODULE RADAR COST ANALYSIS

NORDEN DIVISION
UNITED TECHNOLOGIES CORPORATION
NORWALK, CONNECTICUT 06856

July 1977

Technical Report AFAL-TR-77-26

FINAL REPORT FOR PERIOD 1 JUNE 1976 - 30 NOVEMBER 1976

Approved for public release: distribution unlimited.

Prepared for

AIR FORCE AVIONICS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORY
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AFB, OHIO 45433

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This final report was submitted by the Norden Division of United Technologies Corporation, Norwalk, Connecticut, under contract F33615-76-C-1306, job order 60960567, with the Air Force Avionics Laboratory, Wright-Patterson Air Force Base, Ohio. Mr. Neil DiGiacomo, AFAL/DHE, was the Government Project Engineer. The contractor's activity was under the direction of Mr. Robert Hoefle as Project Engineer.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFAL-TR-77-26	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) STANDARD ELECTRONIC MODULE RADAR COST ANALYSIS FINAL REPORT		5. TYPE OF REPORT & PERIOD COVERED Final 1 June 1976 - 30 Nov 1976
		6. PERFORMING ORG. REPORT NUMBER 1266-R-0007
7. AUTHOR(s) R. Hoefle R. Archbald R. Lipeles		8. CONTRACT OR GRANT NUMBER(s) F33615-76-C-1306
9. PERFORMING ORGANIZATION NAME AND ADDRESS United Technologies Corporation Norden Division Norwalk, Connecticut 06856		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 6096-05-67
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Avionics Laboratory (DHE) Air Force Systems Command Wright-Patterson AFB, Ohio 45433		12. REPORT DATE July 1977
		13. NUMBER OF PAGES 99 100 99
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

SEM	Life Cycle Cost	BITE
SEMR	Logistic Support Cost	
AN/APN-59B	LSC Model	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The standard electronic module radar (SEMR) is a redesigned AN/APN-59B weather, navigation, beacon radar system using standard electronic modules wherever possible. Two configurations of SEMR have been developed to permit use in C-130 and C-135 or in C-141 aircraft. Both configurations include built-in test equipment (BITE) to provide fault detection and isolation to 4 to 6 modules.

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This cost analysis encompasses life cycle cost (LCC) estimates for each SEMR configuration and for a mixed force comprising both configurations over 10, 15, and 20-year operating periods. Each LCC estimate is repeated for three maintenance concepts, throwaway, base repair and depot repair, and for five variations in level of BITE ranging from no BITE to BITE to an individual module. Finally, the minimum cost maintenance concept for SEMR is determined analytically and verified by computer model runs.

Results of the analysis show that with few exceptions the cost and reliability of SEMs is such that it is cheaper to discard than to repair failed modules. Also, base repair is shown to be much more costly than depot repair of either SEM or non-SEM modules in all cases. Finally, no significant differences in LCC are found over the range of BITE levels assumed in the analysis.

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SECTION I
SUMMARY

The Standard Electronic Module Radar (SEMR) was developed by the Naval Avionics Facility, Indianapolis (NAFI) under funding provided by AFAL. SEMR is a redesigned AN/APN-59B weather, navigation, beacon radar system using standard electronic module (SEM) technology. This system is currently undergoing flight tests to provide information on the suitability of existing SEM technology for avionics applications. This SEMR Cost Analysis Program was initiated in June, 1976, to provide a detailed investigation of potential cost savings resulting from use of standard modules and SEM maintenance concepts.

1.1 SCOPE

Two SEMR configurations have been developed for use either in C-130 and C-135 or in C-141 aircraft. The C-141, or pilot operable configuration, has one indicator and substitutes a pilot control box for the remote control box (R/T) and display control box used in the C-130/135 configuration. The C-130/135 has two indicators and a remote control box (BITE), which is not used in the C-141. Beyond this there are slight differences in SEM types and quantities used in the receiver and display electronics unit portions of the systems.

Expected life cycle costs (LCC) were developed for both SEMR configurations independently and for a mixed force including both configurations. Separate calculations were made in each case for operational periods of 10, 15, and 20 years. In addition, LCC for each of these nine cases (3 a/c types x 3 life cycles) was computed for three different maintenance concepts:

a. <u>Throwaway</u> - all SEMs discarded upon failure, and all larger boxes and subassemblies returned to depot for repair.

b. Base Repair - only standard SEMs discarded upon failure, and all other failures repaired at the base. No depot repair used.

c. Depot Repair - same as b. but all repairs made at depot. No base repair used.

These 27 baseline computations use the existing SEMR configurations which incorporate built-in test equipment (BITE) capability for isolation of faults to 4 to 6 modules. Four additional sets of LCC computations were made to provide information on the effect of varying the level and confidence of BITE. These include no BITE, BITE to a group level (i.e., microwave, timing and control, receiver, etc.), BITE to 8 to 10 modules, and BITE to an individual module.

Finally, an analysis was made to determine the breakeven cost for throwaway vs. repair of individual SEMs. This enabled identification of the minimum cost maintenance concept in which only selected SEMs would be repaired. The analysis shows that breakeven unit cost for a given SEM type is determined not only by repair cost but also by the expected total number of failures for that SEM type. Since the latter depends on MTBF, quantity per system, and total operating hours, the breakeven cost varies with SEMR configuration and operating life. Six additional LCC computations were made to verify these results.

Thus, the SEMR Cost Analysis Program results described herein encompass 141 separate LCC computations. Each computation is the sum of development, acquisition, and logistic support costs. The development and acquisition costs are based on Norden experience in development and production of comparable airborne radars. The logistic support cost estimates are derived from the AFLC Logistic Support Cost (LSC) Model.

In addition to basic SEMR design data, AFAL provided the system use factors (number of aircraft, bases, and flight hours

per month by aircraft type) and a detailed reliability analysis prepared by RADC. This analysis is based on the SEMR prototype configuration and includes recommendations for reliability improvement. These improvements were assumed to have been incorporated in the production versions of SEMR on which the LCC estimates are based. Resulting predicted MTBFs for the two configurations are 204 hours for the C-130/135 and 245 hours for the C-141.

1.2 RESULTS

Figure 1 presents a breakdown of life cycle cost estimates for the three SEMR configurations analyzed. These estimates are for the baseline system with BITE to 4 to 6 modules. Development costs are essentially the same for all aircraft cases considered, but the unit production cost and hence total acquisition cost is affected. This variation in average unit production cost ranges from $98K for the mixed force buy to $116K for the C-141. The C-141 configuration has the highest unit cost in each case, although it actually comprises less hardware. This is due to the learning curve assumption, since for equal quantities the C-141 unit cost would actually be about 15% less than that of the C-130/135 configuration.

The logistic support cost portion of Figure 1 shows that base repair is the most costly maintenance concept in every case. This is due primarily to the cost of establishing base repair facilities. The difference between throwaway and depot repair is generally less than 3% and is probably insignificant in relation to the accuracy of the estimate.

Figure 2 shows the effect on life cycle cost of varying the level of BITE provided. Note that the no BITE configuration is generally the least costly alternative with BITE to 8 to 10 modules next lowest. However, the difference between either of

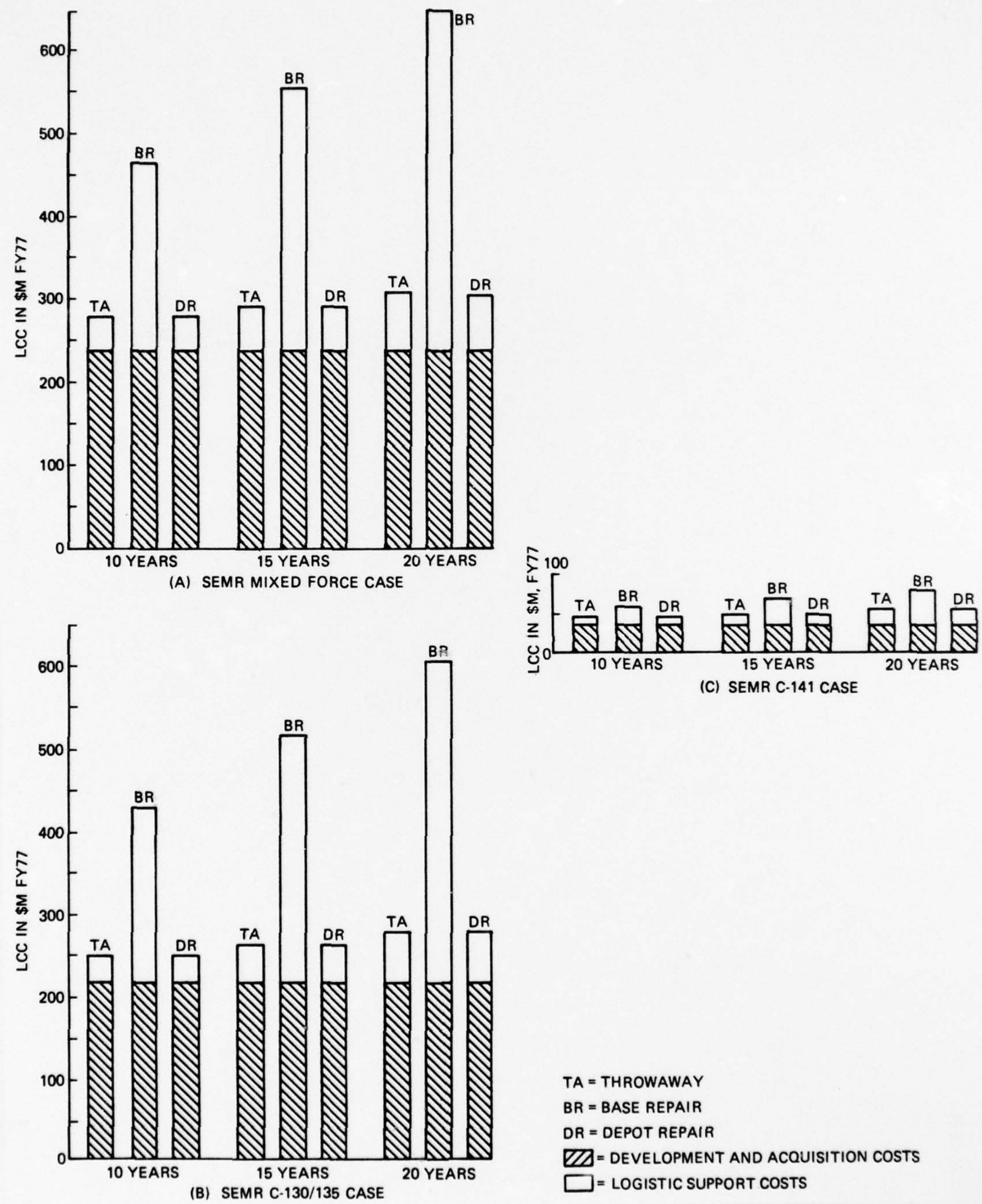

Figure 1. Life cycle costs.

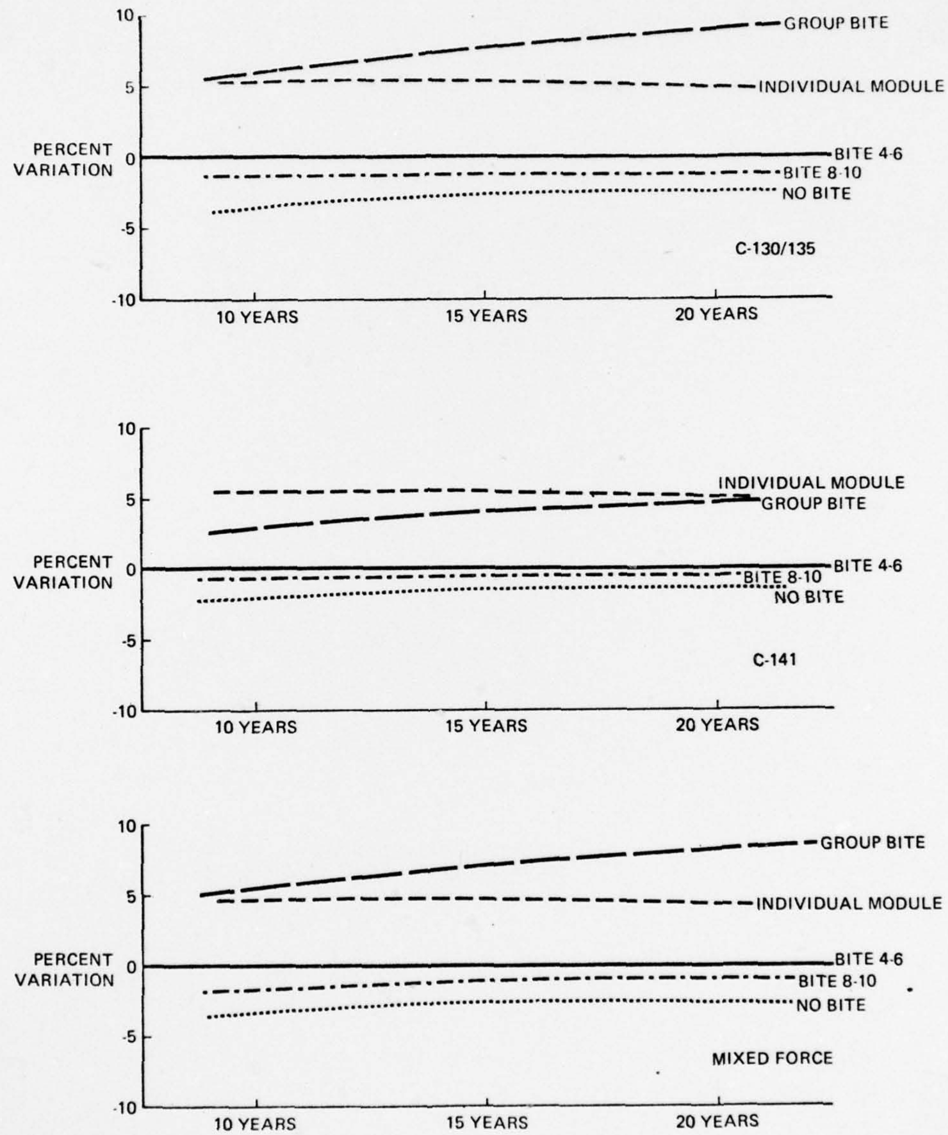

Figure 2. Effect of BITE variations on SEMR LCC.

these and the baseline (BITE to 4 to 6 modules) is less than 4% in every case. This difference is considered insignificant in relation to the accuracy of the estimate. Similarly, except for group BITE which is generally higher, there does not appear to be a significant difference in logistic support costs for the various levels of BITE considered.

Figure 3 shows the difference in logistic support cost estimates between the minimum cost cases and the baseline (BITE to 4-6 modules). In each of the six minimum cost cases, only selected SEMs are repaired. All other SEMs are thrown away upon failure. Otherwise the maintenance concept is the same as for depot repair. While the results for these cases do show slightly lower costs, the savings are insignificant in relation to the accuracy of the estimate. Only base repair can be definitely eliminated on the basis of this analysis. No comparison is shown for the C-141 because analysis shows that throwaway is clearly the least costly alternative in that case.

1.3 CONCLUSIONS AND RECOMMENDATIONS

It is not possible to determine on the basis of this investigation alone whether use of SEMs provides a savings in avionics system life cycle cost because comparable data for the AN/APN-59B and SEMR are not available. However, much data on cost and failure rate experience with the APN-59B undoubtedly exist, so comparative cost estimates could be developed. Such an investigation is highly recommended.

It should be recognized that the LCC estimates produced in this investigation assume that these are the only SEMR-equipped aircraft in inventory and that SEMR is the only Air Force avionics system in which SEMs are used. Thus, the results do not reflect some potential cost savings accruing to SEM usage, e.g., reduction in spares inventory, supply system entry

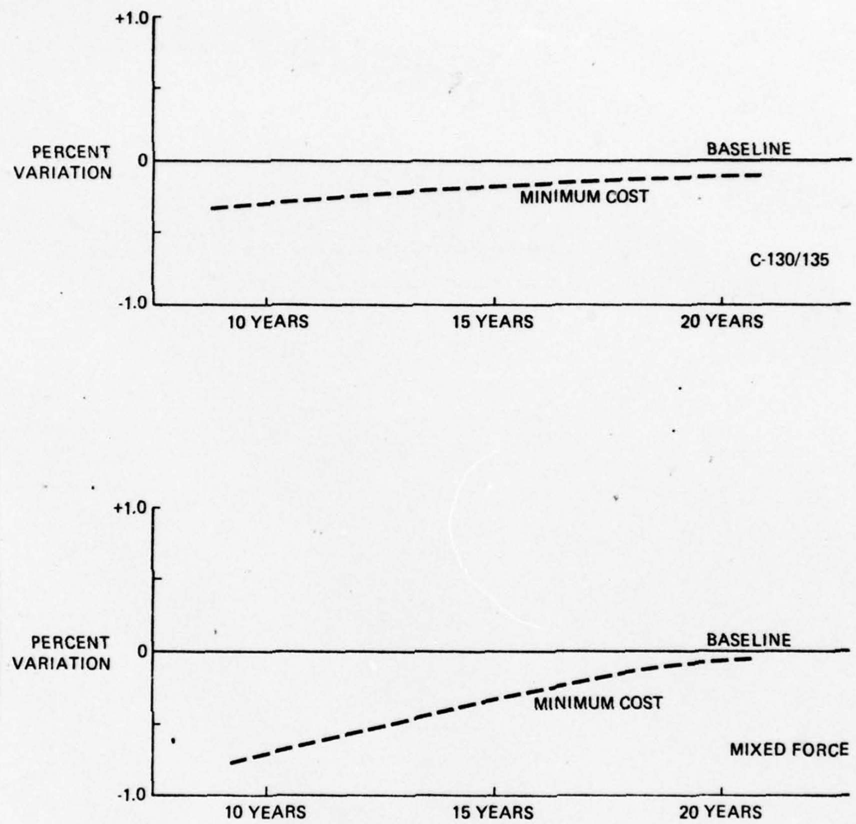

Figure 3. Logistic support cost differential for minimum cost cases vs. depot repair.

and module acquisition costs. Estimates of these savings should also be included in any furhter investigation of SEM costs.

Other principal conclusions of this investigation are briefly summarized as follows:

a. With the exception of a very few module types it is less costly to discard failed SEMs than to repair them.

b. The throwaway vs. repair decision must be made on an individual SEM basis, because it depends not only on module cost but also on expected number of failures over the operational use period.

c. For those SEMs that should be repaired, only depot repair need be considered, since the costs associated with establishing intermediate (base level) test and repair facilities far outweigh potential savings.

d. On the basis of SEMR cost analysis results, all repairs (both SEM and non-SEM) can be made more economically at depot level. Thus, for this radar at least, intermediate or base level repair could be eliminated.

e. It is less costly to spare modules rather than first line units (FLUs), providing that fault isolation capability to the module level exists either through BITE or base test equipment. If additional test equipment must be provided, cost of this capability must be weighed against the savings in pipeline costs obtained through sparing lower cost modules.

SECTION II
PROGRAM OBJECTIVES

The modern dilemma of high logistics costs, equipment proliferation, increased complexity, low reliability, and ever increasing inflation rate coupled with defense budget limitations all force a critical reappraisal of avionic system life cycle costs.

Numerous studies have identified increased standardization as a viable approach to significantly reduced avionics equipment life cycle costs. Cost savings from 20% to greater than 50% have been forecasted, but unsubstantiated.

The Navy Standard Electronic Module Program (SEMP) has attempted to reduce costs through standardization by developing a library of standard electronic modules (SEMs) with standard form and mechanical interfaces and with commonly used electronic functions. The push for increased performance in past development programs has severely restricted usage of SEMs and, as a consequence, limited the availability of cost savings data.

AFAL has funded a program with the Naval Avionics Facility Indianapolis (NAFI) to redesign an AN/APN-59B weather, navigation, beacon radar system utilizing SEM technology. The Standard Electronic Module Radar (SEMR) uses over 300 SEMs of more than 90 types and incorporates a high level of BITE (fault isolation to 4 to 6 modules). This system is serving as a demonstration vehicle to provide information on suitability of existing SEM technology for avionics applications and provide a base for detailed investigation of potential cost savings resulting from standardization and SEM maintenance concepts.

The investigations performed in the SEMR Cost Analysis Program reported herein are designed to provide a detailed evaluation of the impact of the SEM philosophy on equipment life cycle cost, including variations in maintenance structure, level of BITE, and throwaway vs. repair of modules. Four distinct analyses are included:

a. Total LCC estimate for SEMR installed in USAF C-130 and C-135 aircraft.

b. Total LCC estimate for SEMR (pilot operable configuration) installed in USAF C-141 aircraft.

c. Analyses to evaluate the impact on the above LCC estimates of variations in maintenance structure, throwaway vs. repair concepts, and level and confidence of BITE.

d. Determination of SEMR minimum LCC.

2.1 LIFE CYCLE COSTS

Life cycle costs include: (1) development costs required subsequent to the present SEMR demonstration prototypes (e.g., production engineering, preproduction models, and full military qualification); (2) acquisition costs (e.g., system hardware, initial spares, training, documentation, AGE, introduction of new parts into the federal supply system, and airframe integration costs); and (3) total logistics support costs (e.g., replenishment spares, support and test equipment, update technical data and manuals, manning (training and crew requirements), administration, and supply for life cycles of 10, 15, and 20 years).

The basic SEMR configuration is designed for use in C-130 and C-135 aircraft. The SEMR design, however, also includes provisions for a pilot operable configuration to be used in C-141 aircraft. Through removal of a limited number of modules and addition of a pilot control box, the SEMR can be used by the pilot for weather search. Life cycle cost estimates are included for the C-130/135 and C-141 versions of SEMR both individually and as part of a mixed force comprising all three aircraft types. These estimates are based on a design analysis performed by Norden and the following inputs provided by AFAL:

a. production quantities

b. number of aircraft (by type)

c. number of bases

d. system installation cost

e. Air Force maintenance structure (flight line, intermediate, depot)

f. SEMR design data, parts list, and reliability predictions.

2.1.1 Development Cost

The first major element of SEMR LCC is development cost, which includes all costs involved in proceeding from the present SEMR prototype demonstration model to full scale production. This includes, for example, the cost of production engineering, preproduction models (prototype), procurement data package, and full military environmental qualification. It also includes the cost of module qualification for those SEMs made standards as a result of this program.

2.1.2 Acquisition Cost

The second major element of SEMR LCC is acquisition cost which includes those costs (recurring and nonrecurring) expected under a procurement of SEMR in the quantities furnished by AFAL. The acquisition costs of existing standard modules are obtained from commercial vendors. The costs of nonstandard portions of the SEMR are determined by Norden. Cost of system installation and Government program management during the acquisition phase are included as part of acquisition costs.

2.1.3 Logistics Support Cost

The logistics support costs for life cycles of 10, 15, and 20 years are calculated based upon the existing SEMR design, reliability predictions, and maintenance structure furnished by AFAL. The SEMR BITE circuitry will detect and isolate to a group of 4 to 6 modules or equivalent functional entity for nonmodular portions of the systems. The assumptions made based upon this BITE design include: (1) incremental removal and replacement of the isolated modules until the fault is corrected; (2) the failed modules are throwaway items; (3) subassemblies not isolated to a reasonable level are returned to the depot for repair; (4) no intermediate (base shop) level repair is required; and (5) the only peculiar support equipment is that required to fault isolate repairable items at the depot. Logistics support costs also include initial and replacement spares, documentation and updating of technical data and manuals, manpower (training and crew requirements), introduction of new parts into the Federal Supply System, and administrative and supply support.

2.2 COST SENSITIVITY ANALYSIS

The cost data developed for the two basic SEMR configurations are used as the baseline for a cost sensitivity analysis to evaluate the impact of LCC of variations in maintenance structure, throwaway versus repair, and level/confidence of BITE. For this analysis, the baseline assumptions are modified to examine the effect on total cost of base or depot repair of SEMs, and input data values are adjusted to determine the effect of four other levels of BITE.

2.2.1 Support Structure and Repair Concepts

Cost sensitivities associated with throwaway versus repair concepts are evaluated to determine the optimum level of repair which minimizes life cycle costs. Areas addressed under this analysis include:

a. Is it cheaper to repair the modules?

b. If it is cheaper, at what level should they be repaired (intermediate or depot)?

c. Can one or more levels of the maintenance organization be eliminated?

d. Is it cheaper to spare FLUs rather than modules?

e. At what maintenance level should the nonmodular portions of the SEMR be repaired?

f. Is there a maximum throwaway cost that can be associated with the modules?

2.2.2 Level/Confidence of BITE

The levels and confidence of BITE are varied to evaluate the life cycle cost sensitivities of BITE concepts. The BITE levels evaluated are: (1) no BITE; (2) BITE to the FLU/group;

(3) BITE to a group of 8 to 10 modules; (4) BITE to a group of 4 to 6 modules, and (5) BITE to the individual module. This is accomplished by estimating the costs of circuitry, test equipment, and support posture/structure as the levels and confidence of BITE change.

2.3 SEMR MINIMUM LIFE CYCLE COST

Finally, an analysis of LSC model inputs is made to determine the design and logistics support structure that would result in the lowest LCC for operational use periods of 10, 15, and 20 years. These findings are then verified by additional LSC Model runs and the results analyzed in an attempt to derive an optimum general maintenance philosophy for SEMs.

SECTION III
LIFE CYCLE COST MODEL

Total life cycle cost is the sum of logistic support costs, development costs, and acquisition costs. Elements of the latter two require little or no computation beyond that involved in estimating their values. Thus, there is little advantage in using a computer to total these costs. In addition most of the specific cases to be examined involve variations that affect logistic support costs only. The most efficient approach, therefore, is to obtain total life cycle cost estimates by manually adding estimates for the development and acquisition cost elements to LSC Model-derived operating and support cost elements. Figure 4 lists the actual cost elements included in each phase of SEMR life cycle cost.

3.1 DEVELOPMENT COSTS

Development costs include all items necessary to fabricate preproduction prototypes to complete, released, engineering definition. These are estimated in the same manner as hardware development proposals using the same techniques and data base. Each estimate includes the following items:

a. Breadboard and test - the small amount of developmental effort necessary to incorporate changes, dictated by prototype system testing, into the design. This item also includes some testing of minor redesigns resulting from production engineering changes to the lab-built prototype system.

b. Preparation of data items - labor to upgrade the development drawings to a complete set of manufacturing drawings in accordance with MIL-D-1000.

DEVELOPMENT PHASE	ACQUISITION PHASE	OPERATION & SUPPORT PHASE
PROJECT/PROGRAM MANAGEMENT	FACTORY TOOLING	INITIAL AND REPLACEMENT SPARES
PRODUCTION ENGINEERING	FACTORY TEST EQUIPMENT	ON-EQUIPMENT MAINTENANCE
BREADBOARD AND TEST	MAJOR SYSTEM EQUIPMENT	OFF-EQUIPMENT MAINTENANCE
PREPRODUCTION MODELS	INSTALLATION	INVENTORY ENTRY AND SUPPLY MAINTENANCE
DATA	AF PROGRAM MANAGEMENT	SUPPORT EQUIPMENT
SYSTEM QUALIFICATION	TECHNICAL DATA[2]	PERSONNEL TRAINING AND TRAINING EQUIPMENT
NEW SEM STANDARDS[1]	(SUPPLY SYSTEM ENTRY)[3]	MANAGEMENT AND TECHNICAL DATA
SUPPORT TO AF TESTING	(INITIAL SPARES)[3]	FACILITIES
SPARES	(INITIAL TRAINING)[3]	
AF QUALIFICATION		
AF PROGRAM MANAGEMENT		
GFE		

NOTES: 1. SELECTED MODULES ONLY
2. EXCEPT MANUALS WHICH ARE INCLUDED IN LSC MODEL
3. NORMALLY CONSIDERED AN ACQUISITION COST BUT INCLUDED IN LSC MODEL

Figure 4. Cost elements of SEMR life cycle cost phases.

c. Fabrication of preproduction prototype units - all factory labor, purchases, production engineering support and other costs associated with the fabrication of the prototypes.

d. System qualification - contractor and Air Force qualification tests. Contractor testing includes all hardware, test and refurbishment costs. In addition to conventional system testing a separate line item is included showing estimates of contractor and Government costs associated with the qualification of certain SEMs as standards. This is based on a listing of those SEMs developed specifically for the SEMR program, that, because of quantity or potential usage on other systems, should be qualified as standards.

e. Program management - contractor and government project and program management costs associated with the system development effort.

3.2 ACQUISITION COSTS

Acquisition costs include all recurring and non-recurring items associated with procurement, installation and integration of the required number of systems into the operational force. As noted in Figure 4 certain items often considered to be acquisition costs are treated as operating and support costs for this investigation because they are specifically included in the LSC Model.

Acquisition cost element estimates are based on the equipment quantities specified by AFAL. The contractor portion of these costs is derived using the same data base and techniques as would be used in preparing a hardware production proposal. Each estimate includes the following items:

a. Design and fabrication of factory tooling and test equipment - preparation of operation sheets and of other procedures necessary to support the production quantities. The associated production rate used in each case is the one which results in minimum production costs.

b. Engineering changes - development and incorporation into the design of changes found necessary as a result of qualification testing.

c. Installation - cost of installation kits and airframe integration as supplied by AFAL.

d. Major system equipment - total manufacturing fabrication costs including all purchased parts, labor and engineering support. Estimates assume purchase of all special SEM and non-SEM hardware. Standard SEMs are assumed to be GFE.

e. Technical data - preparation of data items based on an estimate of the required data.

f. Program management - cost of contractor and government project and program management associated with items a. through e. above.

3.3 LOGISTIC SUPPORT COSTS

The LSC Model used in the SEMR Cost Analysis Program was developed by AFLC as a tool for computing estimates of expected support costs which might be incurred by adopting a particular design or choosing a certain design alternative. It does not provide total life cycle costs but does produce detailed

estimates of operating and support costs down to the FLU level. For purposes of this investigation inputs are structured to obtain costs to the module level.

In the LSC Model, costs for each subunit are obtained by summing seven cost elements. The sum of these totals for all subunits is then added to three additional cost elements to obtain the total logistic support cost. Thus, the model includes ten basic cost equations with the first seven being repeated for each subsystem. This model has been modified slightly by Norden to provide a further breakout of costs for the first eight equations. Specific costs computed by the ten equations of the LSC Model together with the Norden breakout (two-digit subscripts) are discussed below.

Definitions for the LSC model variables are presented in Appendix B, and the basic equations are given in Appendix C. Two principal advantages are provided by the more detailed Norden breakout of these equations: (1) it facilitates determination of major cost elements; and (2) it enables manual extrapolation of costs for other operational life periods without making additional computer runs. Specific factors for converting 10-year costs to 15 and 20-year life cycles are shown in Figure 5. Note that different factors are required in many cases to convert subequations of a given basic equation.

One other modification of the basic LSC Model is used in the SEMR cost analysis. Certain standard cost factors are escalated to FY-77 values so that all costs are in consistent year dollars. The escalation factors used were obtained from the Office of the Comptroller of the Army.

3.3.1 C_1 = Initial and Replacement Spares Cost

This gives the initial investment cost of spares necessary to support the repair pipelines plus the purchase cost of spares to replace condemned subunits. The computation includes a spares safety level quantity to provide protection against fluctuation in item demand. This quantity is determined on the basis of an expected backorder criterion.

C_{11} = Cost of Base Pipeline Spares

C_{12} = Cost of Depot Pipeline Spares

C_{13} = Cost of Condemnations

3.3.2 C_2 = On-Equipment Maintenance Cost

This gives flight line maintenance labor costs to perform corrective maintenance in place or to remove and replace subunits for subsequent repair. It also includes labor costs to perform scheduled maintenance and inspections on the subsystem.

C_{21} = Cost of Unscheduled Maintenance Labor

C_{22} = Cost of Scheduled Maintenance Labor

3.3.3 C_3 = Off-Equipment Maintenance Cost

This gives labor and material costs for base and depot maintenance facilities to diagnose, repair or attempt to repair subunits. It also includes associated packing and shipping costs for items returned to depot for repair.

C_{31} = Cost of Base Maintenance Labor and Materials

C_{32} = Cost of Depot Maintenance Labor and Materials

C_{33} = Cost of Packing and Shipping

3.3.4 C_4 = Inventory Entry and Supply Management Costs

This gives the management cost to introduce new line items into the Air Force inventory as well as recurring supply management costs.

C_{41} = Cost of Government Supply System

C_{42} = Cost of Base Supply System

3.3.5 C_5 = Support Equipment Costs

This computes the cost of peculiar support equipment based on the anticipated workload and servicing capability. Cost of necessary additional units of common support equipment is also included.

C_{51} = Cost of Base Peculiar Support Equipment

C_{52} = Cost of Depot Peculiar Support Equipment

C_{53} = Cost of Base and Depot Common Support Equipment

3.3.6 C_6 = Cost of Personnel Training and Training Equipment

This gives the initial and recurring costs to train maintenance personnel (instruction and training materials) and the cost of peculiar training equipment required for the subsystem.

C_{61} = Cost of Base Maintenance Personnel Training

C_{62} = Cost of Depot Maintenance Personnel Training

C_{63} = Cost of Training Equipment

3.3.7 C_7 = Cost of Management and Technical Data

This gives the cost for Technical Orders (TOs), overall manuals and other special technical documentation or repair instructions. It also computes maintenance labor costs to complete on- and off-equipment maintenance records, supply transaction records and transportation forms.

C_{71} = Cost of Labor for Completing Unscheduled Maintenance Forms.

C_{72} = Cost of Labor for Completing Scheduled Maintenance Forms

C_{73} = Cost of Maintenance TOs and TMs

3.3.8 C_8 = Facilities Costs

This gives the cost of special base and depot facilities (including utilities) necessary for operation and maintenance of the subsystem.

C_{81} = Cost of Depot Maintenance Facilities

C_{82} = Cost of Base Operation and Maintenance Facilities

3.3.9 C_9 = Fuel Consumption Cost

For systems with propulsion subsystems, this equation gives the cost of fuel for the operational life of the system. This is not used in the SEMR analysis.

3.3.10 C_{10} = Cost of Spare Engines

When applicable, this gives the cost of whole spare engines required in the base and depot pipeline to support the weapon system. This is not used in the SEMR analysis.

Equation	15-year Factor*	20-year Factor*
C_{11}	1.0	1.0
C_{12}	1.0	1.0
C_{13}	1.5	2.0
C_{21}	1.5	2.0
C_{22}	1.5	2.0
C_{31}	1.5	2.0
C_{32}	1.5	2.0
C_{33}	1.5	2.0
C_{41}	1.479	1.957
C_{42}	1.5	2.0
C_{51}	$\frac{1 + 15(COB)}{1 + 10(COB)}$	$\frac{1 + 20(COB)}{1 + 10(COB)}$
C_{52}	$\frac{1 + 15(COD)}{1 + 10(COD)}$	$\frac{1 + 20(COD)}{1 + 10(COD)}$
C_{53}	1.25 - 0.25(CS+IH)	1.5 - 0.5(CS +IH)
C_{61}	1.417	1.833
C_{62}	1.319	1.638
C_{63}	1.0	1.0
C_{71}	1.5	2.0
C_{72}	1.5	2.0
C_{73}	1.0	1.0
C_{81}	1.0	1.0
C_{82}	1.0	1.0

* Factor to be applied to 10-year costs.

Figure 5. LSC model cost conversion factors for extrapolation from 10 to 15 and 20-year life cycles.

3.4 Input Data

Basic data for the investigation were provided by AFAL. These included the system use factors summarized in Table 1, detailed system definition prepared by NAFI, and the SEMR reliability analysis prepared by RADC. Some of the LSC Model input variable values were taken directly from these data, while others were derived by Norden engineers through analysis of the basic data. Some of the latter required use of experience factors and data developed during design, development, and production of similar avionics hardware. Variables relating to BITE variations, repair concept, and support equipment in particular were almost totally derived on the basis of Norden experience.

Tables 2 and 3 show the reliability inputs used in the analysis. These are based on the RADC analysis but incorporate certain revisions to make the results more representative of production hardware. First, some minor design changes in SEM types and quantities made subsequent to the RADC analysis were picked up. Second, in accordance with RADC recommendations, use of MIL-quality parts was assumed in certain of the special modules used. Finally, the revised reliability predictions for individual units were combined to obtain revised values for the two SEMR configurations being investigated.

TABLE 1. SUMMARY OF SEMR SYSTEM USE FACTORS

AIRCRAFT TYPE	NUMBER AIRCRAFT	PERCENT OVERSEAS	NUMBER BASES	FLIGHT HOURS PER MONTH	TOTAL FLIGHT HOURS*		
					10 YEARS	15 YEARS	20 YEARS
C-130	1,237	35	63	43,606	5,232,720	7,849,080	10,465,440
C-135	663	13	57	28,000	3,360,000	5,040,000	6,720,000
C-130/135	1,900	27	120	71,606	8,592,720	12,889,080	17,185,440
C-141	265	0	9	21,426	2,571,120	3,856,680	5,142,240
MIXED FORCE	2,165	24	125**	93,032	11,163,840	16,745.760	22,327,680

*ACTUAL SEMR ON-TIME ASSUMED TO BE 20% GREATER THAN NUMBER OF FLIGHT HOURS

**FOUR BASES COMMON TO C-130/135 AND C-141 AIRCRAFT

TABLE 2. SEMR REVISED RELIABILITY

UNIT	C-130/135 λ (x 10^{-6})	C-130/135 MTBF (HRS)	C-141 λ (x 10^{-6})	C-141 MTBF (HRS)
1. Receiver Transmitter Cabinet				
Receiver*	240.44	4,159	238.13	4,199
Timing and Control*	199.44	5,014	199.44	5,014
BITE*	327.26	3,056	327.26	3,056
System Power Supply*	158.44	6,312	158.44	6,312
Modulator Power Supply*	187.96	5,320	187.96	5,320
R/T Unit	53.27	18,772	53.27	18,772
Local Control Panel (R/T)	133.41	7,496	133.41	7,496
Local Control Panel (BITE)	65.50	15,267	65.50	15,267
Microwave	707.32	1,414	707.32	1,414
2. Modulator Cabinet				
Modulator	46.90	21,322	46.90	21,322
Power Converter	94.93	10,534	94.93	10,534
Magnetron	455.00	2,198	455.00	2,198
3. Ant. Control Electronics Cabinet				
Antenna Control Electronics*	133.49	7,491	133.49	7,491
Antenna Control Unit	41.61	24,033	41.61	24,033
4. Display Electronics Unit Cabinet				
Display Electronics Unit*	615.71	1,624	493.16	2,028
Display Unit	12.02	83,195	12.02	83,195
5. Miscellaneous				
Indicator	1,078.12	928	539.06	1,855
Remote Control Box (R/T)	95.67	10,453	-	-
Display Control Box	102.10	9,794	-	-
Remote Control Box (BITE)*	107.68	9,287	-	-
Pilot Control Box	-	-	155.85	6,416
Junction Box #8	36.43	27,450	36.43	27,450
Junction Box #9	7.98	125,313	7.98	125,313
System Total	4,910.01	204	4,087.16	245

*FLUs which use SEMs

TABLE 3. SEM USAGE IN SEMR RADAR*

KEY CODE	MODULE FUNCTION	SIZE	RCVR	T&C	BITE	REMOTE BITE	SYS PS	MOD PS	ACE	DEU	TOTAL	FAIL RATE $\lambda \times 10^{-6}$
ADL	22K Resistor, Pull-up	1A		4	3	1/0			2	5	15/14	0.60
AEA	AFC Output Scaler, 0-40V	1A	1								1	4.50
AEC	Transmitter Time Delay	1A		1					1	1	3	3.71
AEH	8-Bit A/D with Sample & Hold	1A			1				1	2	4	15.00
AFD	Trigger Driver Assembly	1A		1							1	1.51
BBA	Counter, Up/Down, Binary, Synch	1A		1							1	2.15
BDL	Multiplexer, Digital	1A	1	2	4				2	5	14	2.32
BED	Amplifier, Summing	1A								2	2	4.50
CDJ	High Voltage Filter	1B					1			1	2	3.35
CED	Over/Under Voltage Protector	1A					1	1		1	3	9.47
CFF	Video Buffer Amp, Line Driver	1A	1								1	7.80
CFG	STC Waveform Generator	1B	1								1	7.14
CGK	AC Filament Programmer	1B						1			1	5.22
CGL	Driver, DC to DC Converter	1B					1	3		2	6	6.20
CMH, CZH	Test Point	1A	2	2	1		2	1	2	4	14	1.02
DPR	Auxiliary Power Supply	1G					1	1		1	3	5.28
D2F	Programmed ROM (32 x 24)	1A		1							1	7.58
D2G	Programmed ROM (32 x 24)	1A		1							1	7.58
EAB	Pull-up Resistor Network	1A			1						1	0.52
EEC	Modulator Voltage Select	1A						1			1	1.20
EGA	BITE Signal Conditioner	1A	1		1			1		1	4	0.60
EHP	12V Regulator & Pwr Fail Reset	1A			1						1	2.80
EHR	Computer Interface	1A			1						1	3.56
EPM	Under Voltage Relay	1B		3							3	20.39
FAQ	Op Amp Assembly	1B					1	2		2	5	18.73
FAR	Output Overvolt-Overcurrent Limit	1B					1	1		2	4	9.51
FEG	High Voltage Pos Series Reg	1B	1				1			1	3	9.06
FEH	Sample and Hold	1A	1								1	2.23
FFE	Regulator	1C	1				4	3		4	12	5.23
FHA	Triple 4-Bit Binary Count Schottky	1A		4						3	7	2.35
GAE	Triple Switch	1B		1				2	2		5	1.22
GAF	Regulator	1C	1				1			1	3	6.69
GBD	FTC or Video Select Switch	1A	3/2								3/2	2.31
GDJ	Latch	1A			3				1	6/4	10/8	2.61
GDM	Counter, Up/Down Binary	1A								2/1	2/1	2.58
GDN	Decoder, Binary	1A			1						1	2.39
GEE	Comparator, Analog	1A								2	2	3.63
GVQ	Oscillator, Xtal, 12.288 MHz	1A		1						1	2	0.71
GZB	Octo-Decimo Buffer Non-Invert	1A			2						2	2.29
HRH	Microprocessor	1A			1						1	23.20
JDB	Comparator, Magnitude	1A								4	4	2.71
KDE	Amplifier, IF	2B	1								1	55.49
KDQ	Multiplexer, Digital	1A		1					1	5/3	7/5	3.50
KDR	Flip-Flop, D Type	1A		3	1	1/0			1	2	8/7	2.04
KLQ	Rectifier/Filter	1G					1				1	4.24
LDN	Gate, NAND	1A		1							1	1.53
LDQ	Gate, NAND	1A							5	9	14	1.80

TABLE 3. SEM USAGE IN SEMR RADAR* (CONTINUED)

KEY CODE	MODULE FUNCTION	SIZE	RCVR	T&C	BITE	REMOTE BITE	SYS PS	MOD PS	ACE	DEU	TOTAL	FAIL RATE $\lambda \times 10^{-6}$
MUM	Isolator, Optical	1A		5	6	2/0			3	5	21/19	6.60
NQD	Quad 4-input Analog Multiplier	1A	2		3		2	3	1	6/4	17/15	5.50
PFB	Filter	1C					3			8	11	5.71
PQD	Quad Monostable Multivibrator	1A	1	1							2	3.28
RAD	Lin/Log Gain	1A	1								1	8.80
RBA	Ramp Clock Generator	1B					1	1		1	3	6.36
RBB	Integrator & Mode Select	1A	1								1	2.77
RBF	Gate, NAND	1A	1	8	3						12	1.21
REC	Comparator	1A					1	3		2	6	5.25
RRM	PROM (Rev A)	1A			15						15	10.22
SHU	Generator, Function (LSB)	1A								2/1	2/1	4.64
SHV	Octant/Quadrant	1A								2/1	2/1	7.44
SHX	Processor, Error, S/D	1B								2/1	2/1	7.44
SHY	Generator, Function (MSB)	1A								2/1	2/1	6.00
SQS	Clock Driver (1.5 MHz)	1A			1						1	3.19
TEZ	AC Filament Sense	1B						2			2	21.43
TPT	Power Supply (Converter)	2G					1			1	2	23.21
UET	Mixer-Terminator Module	1B			1						1	1.30
UFS	D/A Converter	1A		2							2	7.31
UFZ	Filter, IF	2B	1								1	50.13
UGW	Timer	1A		2					2		4	4.87
UMU	LED Display	1A		2						2	4	4.36
VBS	Mod/Demodulator	1B	1								1	5.87
VEW	Sweep Generator	1A								2	2	3.33
VFT	Integrator/Filter	1A	1								1	4.98
VHU	Active Filter	1B							1		1	2.42
VJX	DEU Catch-all #1	1A								1	1	0.77
VLY	DEU Catch-all #2	1A								1	1	1.42
WET	Unblank Driver	1A								1	1	6.21
WHV	Amplifier, IF	2B	1								1	42.37
WHW	Comparator, Analog	1A								1	1	6.18
WKX	Diode/Resistor	1A				1/0					1/0	2.91
WRU	Relay Module	1B							1		1	2.41
WSY	3019 Transistor Driver	1B							2		2	4.41
WXZ	BITE Signal Cond. #1	1B							1		1	10.48
XEV	Capacitor	1A		1							1	0.56
XFW	Amplifier, Summing	1A								1	1	0.89
XJX	BITE Signal Cond. #2	1A							1		1	9.64
XKY	BITE Signal Cond. #3	1A							1		1	1.89
XPU	Power Converter, Display	2G								1	1	29.76
XYS	RAM	1A			2						2	10.69
YBZ	Tri-state Buffer	1A		2	6						8	2.29
YEW	Video Driver	1A								1	1	6.93
YPZ	Regulator, Voltage	1D							1		1	16.61
ZBW	Multiplier, A X D	1A								2/1	2/1	2.77
9206	Scott Tee Transformer	1C								2/1	2/1	1.28
U2X	Sine/Cosine ROM	1A								2/0	2/0	33.59

TABLE 3. SEM USAGE IN SEMR RADAR* (CONTINUED)

SYSTEM TOTALS	RCVR	T&C	BITE	REMOTE BITE	SYS PS	MOD PS	ACE	DEU	TOTAL
C-130/135									
Number of Modules	25	50	58	5	23	26	32	117	336
Number of Types	21	23	21	4	16	15	20	47	94
C-141									
Number of Modules	24	50	58	0	23	26	32	102	315
Number of Types	21	23	21	0	16	15	20	46	92

*Where quantities differ in C-130/135 and C-141 versions, they are listed as C-130/C-141.

SECTION IV
SYSTEM DESCRIPTION

4.1 GENERAL

SEMR has been designed by NAFI for use either in C-130 and C-135 or in C-141 aircraft. A WBS for the two configurations is shown in Figure 6. Principal differences are the number of indicators and the ancillary boxes used. These differences stem primarily from the fact that the C-141 does not use a navigator, so that configuration is designed to be pilot operable. Also, there are some minor differences in SEM usage as shown in Table 4.

All SEMs, except those in the remote control box (BITE), are mounted in self-contained replaceable subassemblies consisting only of SEMs, connectors, wiring and structure. The remote control box (BITE) contains only five SEMs, each of which plugs directly into the main unit.

The WBS (Figure 6) shows the breakout of SEMR to the first line unit (FLU) level. An FLU is defined as the first level of assembly below the system level that is carried as a line item of supply at the base level. It usually is the highest level of assembly that is removed and replaced as a unit in order to return the equipment to an operational condition. In the SEMR cost analysis, all SEMs were treated as FLUs in order to obtain logistic support cost data to the module level.

4.2 SPECIFIC

The brief description of major SEMR components presented in the remainder of this section is intended only to provide a background for the cost analysis discussion in the following sections. A more detailed description of the hardware can be found in the NAFI Interim Engineering Report.[1]

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[1] "Standard Electronic Module Radar (SEMR), Interim Engineering Report"; TR 2088; September, 1975; Naval Avionics Facility, Indianapolis, Indiana.

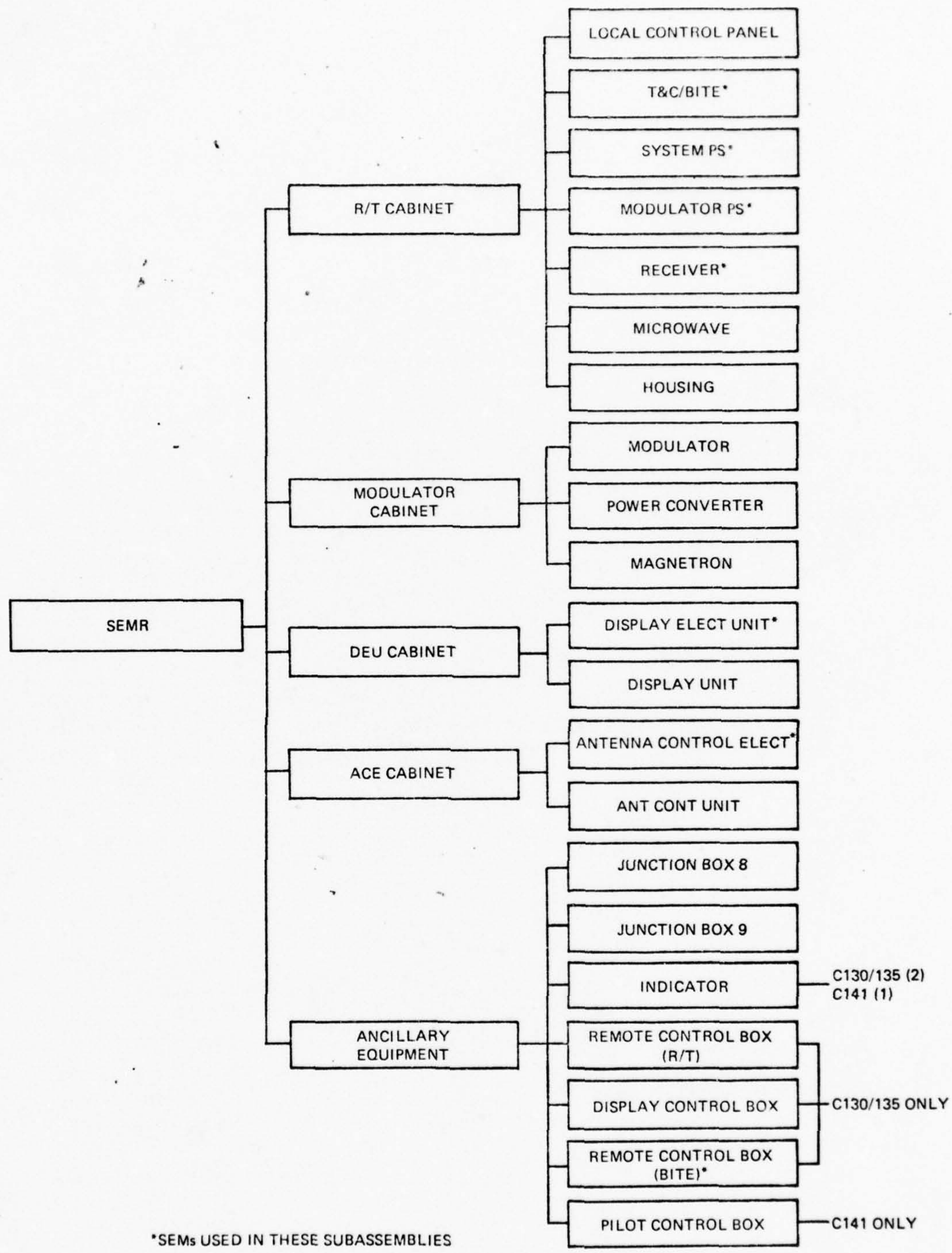

Figure 6. SEMR work breakdown structure (WBS).

TABLE 4. SUMMARY OF SEM UTILIZATION

UNIT	C-130/135		C-141	
	NUMBER OF MODULES	NUMBER OF MODULE TYPES	NUMBER OF MODULES	NUMBER OF MODULE TYPES
T&C/BITE	108	37	108	37
SYSTEM PS	23	16	23	16
MODULATOR PS	26	15	26	15
RECEIVER	25	21	24	21
DISPLAY ELECT UNIT	117	47	102	46
ANTENNA CONTROL ELECT	32	20	32	20
REMOTE CONTROL BOX - BITE	5	4	NA	NA
SYSTEM TOTALS	336	94	315	92

4.2.1 Receiver/Transmitter Cabinet

Figure 7 is a photograph of the R/T cabinet showing the SEM mounting panels. At the top of the cabinet is the local control panel which also is normally covered. From this position, a maintenance technician can operate most of the functions of the cockpit controls plus some test functions not otherwise available.

Inside the cabinet are the microwave assembly and four SEM card cages. Timing and control and BITE SEMs are located on a common card cage which swings to the left. System power supply and modulator power supply card cages are mounted back to back on a panel which swings to the right. Receiver SEMs are located on a fourth card cage mounted inside the cabinet. With both panels open, the technician has access to all SEMs and to all microwave modules and adjustments in the microwave unit.

4.2.2 *Modulator Cabinet*

Figure 8 is a photograph of the modulator cabinet. The modulator cabinet mounts to the right of the R/T cabinet, and both are attached to a common mounting plate. The smaller box at the left of the picture contains the power convertor. The magnetron is at the upper right. No SEMs are used in this portion of the radar.

4.2.3 Display Electronics Unit (DEU)

The display electronics unit (Figure 9) consists of two subassemblies, a SEM card cage and a housing containing connectors, harnessing and RFI filters. Since the DEU is capable of driving up to three indicators, only one DEU is required for either the C-130/135 or C-141 configuration.

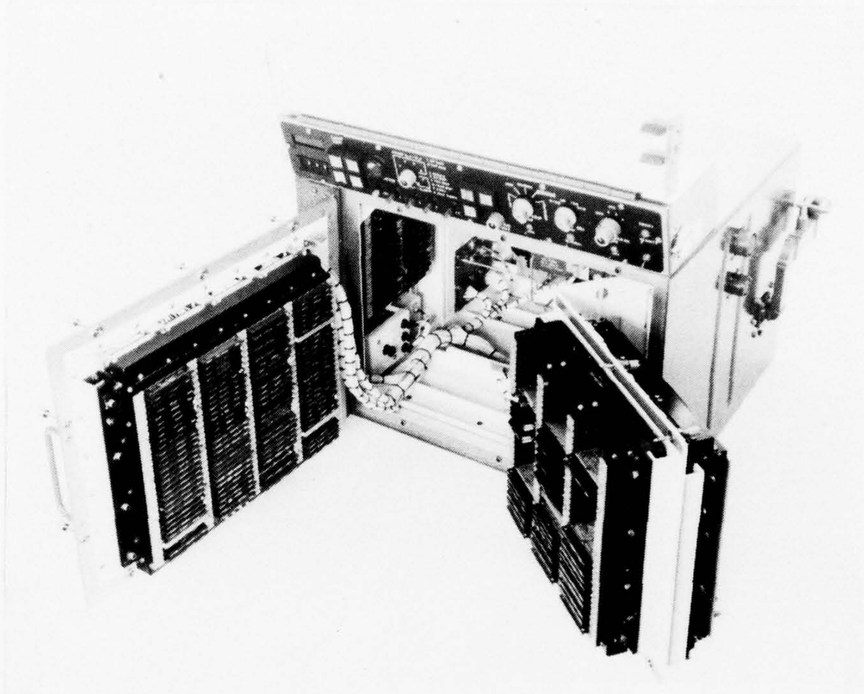

Figure 7. SEMR receiver/transmitter cabinet.

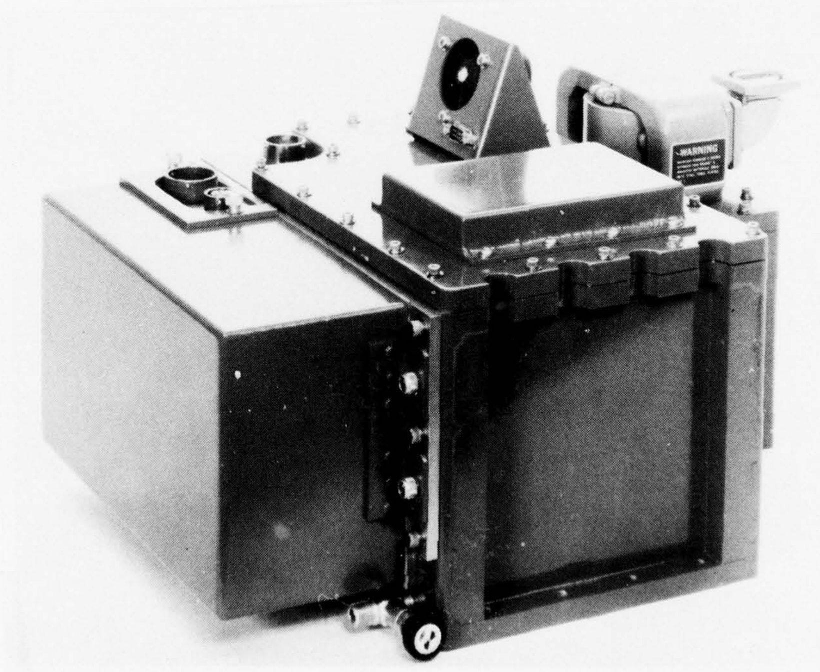

Figure 8. SEMR modulator cabinet.

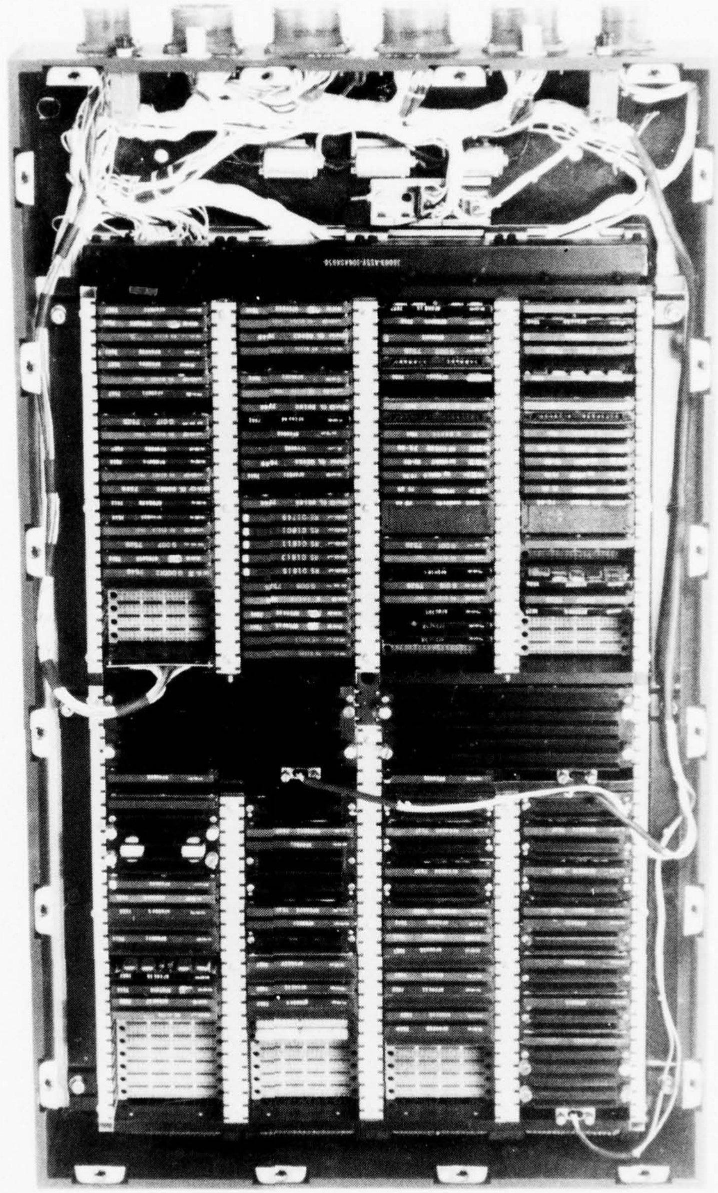

Figure 9. SEMR display electronics unit (DEU).

4.2.4 Antenna Control Electronics (ACE)

The antenna control electronics unit (Figure 10) is packaged similarly to the DEU. It contains two subassemblies, a SEM card cage and a housing containing connectors, harnessing, transformers and discrete components.

4.2.5 Junction Boxes

There are two junction boxes, Junction Box #8 and Junction Box #9. These units provide electrical interfaces between the various units of the radar system. They consist entirely of harnessing, connectors and junction blocks and contain no electronic components other than circuit breakers and relays.

4.2.6 Indicator

Two indicators are used per system in the C-130/135 configuration and one per system in the C-141 configuration. The indicator, is shown in Figure 11. It consists of a front panel with controls, a direct view storage tube and associated circuitry. There are no SEM modules in the indicator.

4.2.7 Control Boxes

There are four control boxes. The remote control box (R/T), the display control box and the remote control box (BITE) are used in the C-130/135 configuration only. The pilot control box is used in the C-141 only. All are of conventional design consisting of discrete components, readouts, switches, pots, etc. Of the four, the remote control box (BITE) is the only one containing SEM modules and is also the only one that does not have an edge lit panel.

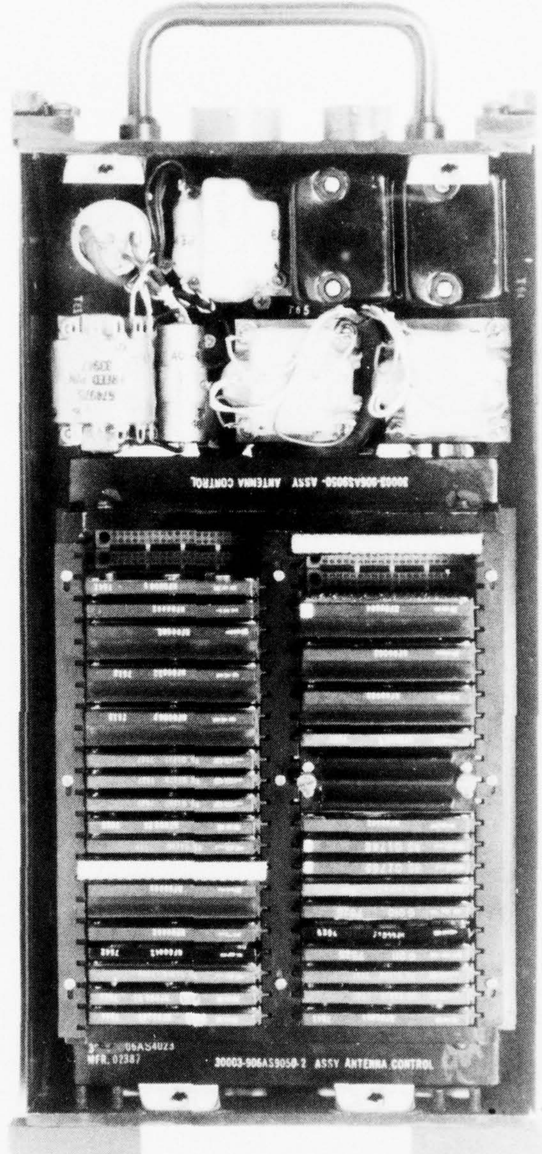

Figure 10. SEMR antenna control electronics unit (ACE).

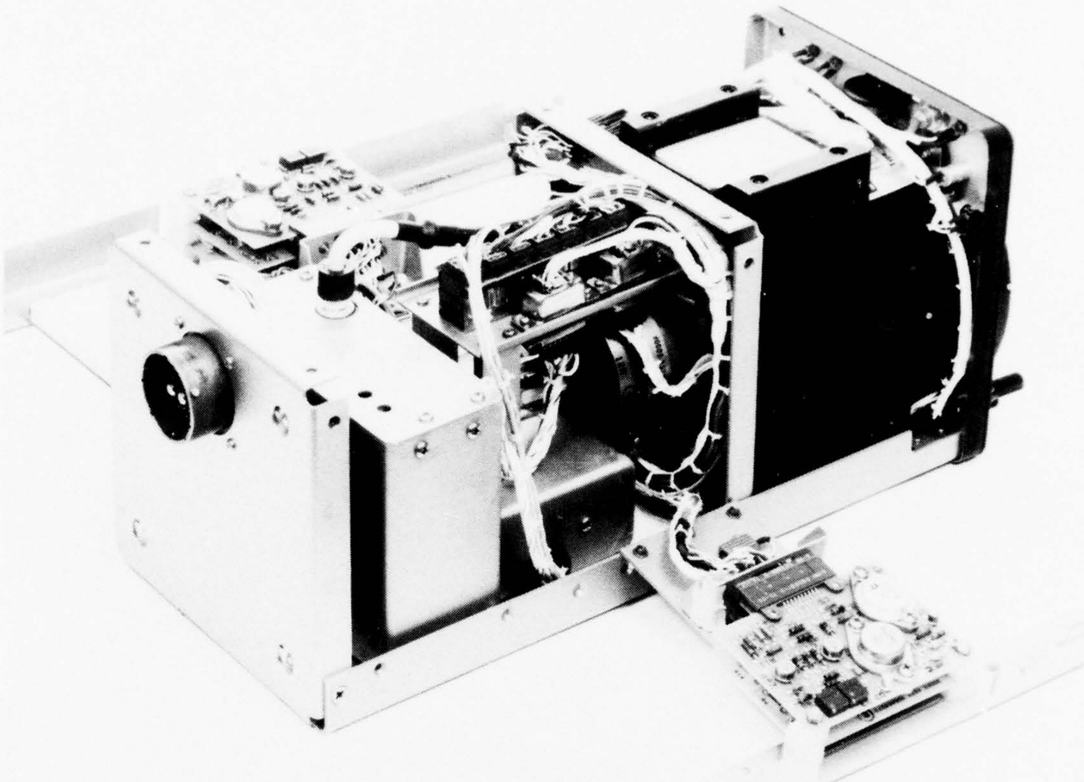

Figure 11. SEMR indicator.

SECTION V
DEVELOPMENT AND ACQUISITION COSTS

Hardware cost estimates for input to the Logistic Support Cost Model are based on system descriptions found in NAFI reports *Standard Electronic Model Radar, Interim Engineering Report,* TR2088, and *Comparison of SEMR with Radar Set AN/APN59B,* 17 November 1975; RADC report *Reliability Analysis of the Standard Electronic Module Radar*, 25 May 1976; and various parts lists and drawings. These were supplemented by discussions with NAFI personnel and by a set of photographs of the major assemblies.

After reviewing this material, it became obvious that there was not enough specific detailed drawings from which to make complete independent "bottoms up" estimates. This coupled with schedule limitations and budget restrictions necessitated the development and application of other estimating techniques. Several were used, each individually chosen as the best for the particular item being estimated. A brief description of these techniques follows.

Vendor Quote

Estimates use current or recent vendor quotes to which factors of material handling, scrap, rework, G&A and profit are added to establish a selling price. In estimating costs for standard SEMs no factors were added as it is believed that the minimum cost would be obtained by Government procurement of these units for supply to the contractor. Therefore for standard SEMs only, vendor quotes are used directly.

Similar To

"Similar to" is used to relate a hardware or task item, as a percentage of a known item, where the known items are based on current production programs or proposals.

Bottoms Up

A "bottoms up" estimate starts with actual material and manufacturing labor estimates. To these are added the support areas of engineering, quality control, administration, test engineering and program management. The hours for these support areas are determined by estimating or using established historical percentages of manufacturing hours. Both techniques have been used.

Parts plus Percent for Labor

This technique is used to estimate a selling price when only parts costs are known and labor cannot be readily estimated. It is based on the fact that labor usually accounts for 20% to 40% of selling price. Obviously, the application of this technique is highly judgemental, and it is the least accurate of the methods used.

In order to apply these various estimating techniques consistently, a set of rates and pricing formula were established. These are summarized on the actual worksheet used for final pricing as Table 5. These rates and support percentages have been chosen to be representative of a general industrial base, rather than any particular contractor.

The results of the hardware cost analyses are shown as Tables 6, 7, and 8. These tables show equipment cost, standard SEM cost and special SEM cost. Prices are for production quantities of 1,000 units. In arriving at these figures, and

TABLE 5. PRICE ANALYSIS FORM WITH ASSUMED RATES

PRICE ANALYSIS

Customer :				O.Q.:
Description :				Date:
Item :				
Engineering Direct Labor	Rate	Hours	Amount	Total
Engineers	11.90			
Engineering Assistants				
Draftsmen				
Technical Publications				
Photo Lab				
Plan & Admin. (Engr)				
Engr. Support				
Total Engineering Direct Labor				
Engineering Overhead	110%			
Manufacturing Direct Labor				
Prototype Shop				
Machining	6.23			
Assembly	5.36			
Packaging & Kitting				
In Line Test	6.44			
Product Assurance (Q.C.)	7.10			
Plan. & Admin. (Mfg)	10.17			
Product Support				
Test Engr. T & TE Design	11.49			
Total Mfg. Direct Labor				
Manufacturing Overhead	165%			
Program Mgmt & Control	13.78			
PM&C Overhead	90%			
Purchases				
Material Handling Charge	8%			
Other Direct Charges (SRO)	5%			
Travel & Living Expense				
Sub-Total				
General & Administrative	25%			
Total Inv Cost				
Profit	12%			
			Sell $	

TABLE 6. SEMR SELLING PRICES AND ESTIMATING TECHNIQUES USED

	Selling Price ($)	Estimating Approach: Vendor Quote	Similar To	Bottoms Up	Parts + % Labor
<u>R/T Cabinet</u>					
Local Control Panel	287				✓
T & C /Bite*	1668				✓
System P.S.*	699				✓
Modulator P.S.*	790				✓
Receiver*	532				✓
Microwave	7459				✓
Housing	5297				✓
<u>Modulator</u>					
Modulator	5393		✓		
Power Converter	6559		✓		
Magnetron	1551	✓			
<u>Display Electronics Unit</u>					
Display Electronics Unit*	2262				✓
Dispaly Unit	2246			✓	
<u>Antenna Control Electronics</u>					
Antenna Control Electronics*	648				✓
Antenna Control Unit	2394				✓
<u>Miscellaneous</u>					
Junction Box #8	1651			✓	
Junction Box #9	968			✓	
Indicator	13074		✓		
Remote Control Box - R/T	2205				✓
Display Control Box	1345				✓
Remote Control Box - BITE*	2194				✓
Pilot Control Box	2547				✓
All Standard SEM	-	✓			
All Special SEM	-			✓	

*These units contain SEM modules. Price shown is for unit less SEM modules.

TABLE 7. STANDARD SEMS

STANDARD SEMS			
CODE	QTY-C130	QTY-C141	PRICE
ADL	15	14	60.00
BBA	1	1	75.00
BDL	14	14	47.00
CMH	14	14	41.00
GDJ	10	8	52.00
GDM	2	1	129.00
GDN	1	1	45.00
KDQ	7	5	73.00
KDR	8	7	33.00
LDN	1	1	29.00
LDQ	14	14	31.00
YBZ	8	8	94.00
IN PROCESS STANDARD SEMS			
BED	2	2	124.00
FHA	7	7	198.00
GEE	2	2	146.00
GVQ	2	2	55.00
HRH	1	1	350.00
JDB	4	4	52.00
MUM	21	19	236.00
RBF	12	12	95.00
SHU	2	1	310.00
SHV	2	1	340.00
SHX	2	1	380.00
SHY	2	1	370.00

TABLE 8. SPECIAL SEMS C130/C141

KEY CODE	SIZE	TITLE	CONN PINS	QTY C130	QTY C141	EST SALES PRICE
AEA	1A	AFC OUTPUT SCALER, 0-4 OV	40	1	1	92
AEC	1A	XMTR TIME DELAY	20	3	3	73
AEH*	1A	8 BIT A/D WITH SAMP & HOLD	40	4	4	136
AFD	1A	TRIGGER DRIVER	40	1	1	145
CDJ	1B	HIGH VOLTAGE FILTER	20	2	2	112
CED	1A	OVER/UNDER VOLT PROT	20	3	3	123
CFF	1A	VIDEO BUF AMP, LINE DRIV	20	1	1	105
CFG	1B	STC WAVEFORM GEN	40	1	1	142
CGK	1B	AC FILAMENT PROGRAMMER	20	1	1	144
CGL*	1B	DRIVER, DC/DC CONV	40	6	6	158
DPR	1G	AUX PWR SUPPLY	40	3	3	322
D2F	1A	PROG ROM (32 x 24)	40	1	1	124
D2G	1A	PROG ROM (32 x 24)	40	1	1	124
EAB	1A	PULL-UP RES NETWORK	40	1	1	76
EEC	1A	MODULATOR VOLT SEL	40	1	1	87
EGA*	1A	BITE SIG CONDITIONER	40	4	4	111
EHP	1A	12V REG & PWR FAIL RESET	20	1	1	78
EHR	1A	COMPUTER INTERFACE	40	1	1	100
EPM	1B	UNDER VOLTAGE RELAY	40	3	3	110
FAQ*	1B	OP AMPL	40	5	5	152
FAR*	1B	OUT OVER VOLT-OVCUR LIMIT	20	4	4	129
FEG	1B	HIGH VOLTAGE POS SER REG	40	3	3	143
FEH	1A	SAMPLE & HOLD	40	1	1	89
FFE*	1C	REGULATOR	40	12	12	180
GAE*	1B	TRIPLE SWITCH	40	5	5	91
GAF	1C	REGULATOR	40	3	3	169
GBD	1A	FTC OR VIDEO SEL SW	20	3	2	84
GZB	1A	OCTO-DECIMO BUFFER	40	2	2	87
KDE	2B	IF AMPL	40	1	1	448
KLQ	1G	RECTIFIER/FILTER	40	1	1	177
NOD*	1A	QUAD 4-IN ANALOG MULT	40	17	15	145
PFB*	1C	FILTER	20	11	11	165
PQD	1A	QUAD MONO MULTI	20	2	2	100
RAD	1A	LIN/LOG GAIN	20	1	1	77
RBA	1B	RAMP CLOCK GEN	40	3	3	161

KEY CODE	SIZE	TITLE	CONN PINS	QTY C130	QTY C141	EST SALES PRICE
RBB	1A	INTEGRATOR & MODE SEL	20	1	1	84
REC*	1A	COMPARATOR	20	6	6	127
RRM	1A	PROM	20	15	15	86
SQS	1A	CLOCK DRIVER (1.5 MHz)	40	1	1	151
TEZ	1B	AC FILAMENT SENSE	40	2	2	207
TPT	2G	POWER SUPPLY	40	2	2	356
UET	1B	MIXER-TERMINATOR	40	1	1	137
UFS	1A	D/A CONVERTER	20	2	2	121
UFZ	2B	IF FILTER	40	1	1	414
UGW*	1A	TIMER	40	4	4	105
UMU*	1A	LED DISPLAY	40	4	4	169
VBS	1B	MOD/DEMOD	40	1	1	132
VEW	1A	SWEEP GEN	20	2	2	112
VFT	1A	INTEGRATOR/FILTER	20	1	1	84
VHU	1B	ACTIVE FILTER	40	1	1	234
VJX	1A	DEU CATCH-ALL 1	40	1	1	75
VLY	1A	DEU CATCH-ALL 2	20	1	1	81
WET	1A	UNBLANK DRIVER	40	1	1	74
WHV	2B	IF AMPLIFIER	40	1	1	300
WHW	1A	ANALOG COMPARATOR	20	1	1	93
WKX	1A	DIODE/RESISTOR	20	1	0	83
WRU	1B	RELAYS	40	1	1	155
WSY	1B	3019 TRANSISTOR DRIVER	40	2	2	126
WXZ	1B	BITE SIGNAL COND 1	40	1	1	140
XEV	1A	CAPACITORS	40	1	1	68
XFW	1A	SUMMING AMPLIFIERS	40	1	1	99
XJX	1A	BITE SIG COND 2	40	1	1	64
XKY	1A	BITE SIG COND 3	40	1	1	75
XPU	2G	DISPLAY, PWR CONVERTER	40	1	1	358
XYS	1A	RAM	40	2	2	160
YEW	1A	VIDEO DRIVER	40	1	1	69
YPZ	1D	VOLTAGE REGULATOR	40	1	1	195
ZBW	1A	AXD MULTIPLIER	20	2	2	113
UZX	1A	SINE/COSINE ROM	40	2	0	117
9206	1C	SCOTT TEE TRANSFORMER	20	2	2	250

*ASSUMED NEW STANDARD SEM AS A RESULT OF SEMR PROGRAMS

in subsequent analyses involving other quantities, a learning curve of 90% for both material and labor was used.

The majority of the contractor development costs were estimated using a "similar to" approach. The SEMR complexity was equated to the SPS-XX, which is a shipboard SEM radar currently in the proposal stage.

A summary of the total development and acquisition cost is given in Table 9. Costs are given for a single buy of 1900 C-130/135 systems, 265 C-141 systems and a combination buy of 2165 systems.

TABLE 9. SUMMARY OF SEMR DEVELOPMENT AND ACQUISITION COSTS ($K, FY77) (BASELINE CONFIGURATIONS: BITE TO 4-6 MODULES)

COST ELEMENT	C-130/135	C-141	MIXED FORCE
DEVELOPMENT			
PROJECT/PROGRAM MANAGEMENT	420	420	420
PRODUCTION ENGINEERING	823	737	864
BREADBOARD AND TEST	191	137	200
PREPRODUCTION MODELS (2)	571	475	584
DATA	728	728	728
QUALIFICATION TESTS			
SYSTEM QUALIFICATION	560	560	560
NEW SEM STANDARDS (12)	160	160	160
SUPPORT OF AF TESTS	35	35	35
TEST SPARES	57	48	58
AF QUALIFICATION TESTS	500	500	500
AF PROGRAM MGMT (2.5 YEARS)	325	325	325
GFE*	0	0	0
DEVELOPMENT PHASE TOTALS	4,370	4,125	4,434
ACQUISITION			
FACTORY TOOLING	99	86	104
FACTORY TEST EQUIPMENT	889	795	933
MAJOR SYSTEM EQUIPMENT	193,800	30,740	212,170
INSTALLATION	19,000	2,650	21,650
AF PROGRAM MGMT**	411	115	468
GFE*	0	0	0
ACQUISITION PHASE TOTALS	214,199	34,386	235,325

*STANDARD SEMs ASSUMED TO BE GFE, BUT INCLUDED IN MAJOR SYSTEM EQUIPMENT COST - NO G&A OR FEE APPLIED TO THAT PORTION

**BASED ON AVERAGE PRODUCTION RATE OF 50 SYSTEMS/MONTH FOR C-130/135 AND MIXED FORCE AND 22 SYSTEMS/MONTH FOR C-141

SECTION VI
MAINTENANCE CONCEPTS

The SEMR cost analysis includes evaluation of three maintenance concepts, throwaway, base repair, and depot repair. In throwaway, all SEMs (standard and special) are assumed to be discarded upon failure, while larger boxes and assemblies are assumed to be returned to depot for repair. In depot repair, only standard SEMs are assumed to be discarded upon failure with special SEMs and larger units repaired at the depot. In base repair, the same SEMs and larger units are assumed to be repaired at the base or intermediate maintenance level.

Results of this analysis are compared in Table 10 for both SEMR configurations and for a mixed force over 10, 15, and 20-year operational periods. The costs shown are logistic support costs only, since development and acquisition costs for any given SEMR configuration do not change with maintenance concept. These results show very little difference between throwaway and depot repair in every case but a significantly higher cost for base repair.

The large cost differential for base repair is due first to the number of bases at which test equipment and facilities must be provided and secondly to the low utilization of this test equipment. For example, in the C-130/135 case, there are 1900 aircraft at 120 bases or about 16 per base. Each aircraft flies about 38 hours per month, and SEMR operating hours are assumed to be 20% greater than this or about 45 hours per month. Using the predicted SEMR MTBF of 204 hours there would be approximately 0.22 failures/aircraft per month or about 3.5 failures/base per month. With this low a utilization rate, it is obviously not cost effective to use base repair. Thus, unless its use can be justified on the basis of other systems, the base repair concept for SEMR can be eliminated.

TABLE 10. SUMMARY OF SEMR LOGISTIC SUPPORT COSTS ($K, FY77) (BASELINE CASE: BITE TO 4-6 MODULES)

AIRCRAFT TYPE	OPERATIONAL LIFE (YEARS)	MAINTENANCE CONCEPT		
		THROWAWAY	BASE REPAIR	DEPOT REPAIR
C-130/135	10	33,855	213,257	33,486
	15	47,173	299,350	46,417
	20	60,490	385,441	59,345
C-141	10	8,890	21,605	9,254
	15	11,922	29,963	12,278
	20	14,951	38,320	15,300
MIXED FORCE	10	39,708	225,463	38,910
	15	55,411	316,648	53,987
	20	71,111	407,832	69,064

The very small differential in logistic support costs between the throwaway and depot repair concepts is not surprising because the only difference is the treatment of special SEMs. These have relatively high MTBFs, low cost, and account for only 30% of the SEMs used although they represent 62% of the SEM types in the radar. As in most radars, the more expensive components of SEMR are those used in the microwave, rf, and high voltage sections. In SEMR the logistic support costs associated with non-SEM portions of the radar constitute more than 60% of the total.

The non-SEM elements of SEMR account for more than 79% of the estimated selling price of the system, so it is not practical to consider a throwaway concept for most of these components. Also, because of their construction, it is difficult to repair the non-SEM FLUs on the aircraft. Since repair of these FLUs at base level maintenance has been shown to be much more expensive than at depot level, sparing of FLUs is cheaper than sparing modules in the non-SEM portions of SEMR. However, the reverse is true of the SEM portions. Modules are easily tested and replaced on the aircraft using no special base level test equipment. These modules should therefore be spared at base level and either discarded upon failure or returned to the depot for repair. An analytic method for making the throwaway vs. repair decision on individual SEM types is described in Section 8.

SECTION VII
BITE VARIATIONS

Sensitivity of SEMR LCC to level and confidence of BITE is determined by examining costs for five BITE levels ranging from no BITE to BITE to an individual module. The effects of these BITE variations on logistic support costs are summarized in Tables 11 through 13 for the three aircraft types examined. Table 14 shows the effect on estimated unit production costs, and Tables 15 through 17 show the effect on total life cycle cost. Because it was not possible within the scope of this analysis to prepare a complete redesign for each BITE variation, these results were obtained by estimates of the effects on individual cost elements.

7.1 BITE to 4 TO 6 MODULES

The present SEMR design with BITE to 4 to 6 modules is used as the baseline to which costs for other BITE variations are compared. In all but the no BITE case, the BITE enables a technician to automatically isolate a fault to a group of modules or an FLU. In SEM portions of the radar, the technician then identifies the faulty module by replacing BITE-identified SEMs one at a time until the fault is corrected. In non-SEM portions, the FLU is replaced. Since BITE systems typically have a level of confidence of 90 to 95%, provision is made in the analysis for replacing the entire SEM card cage for 5% of the faults. The true fault is assumed to be correctly identified at the next higher maintenance level.

7.2 NO BITE

In the no BITE case, SEMs and boxes used strictly for BITE are deleted, but signal conditioning modules in other

TABLE 11. LOGISTIC SUPPORT COST SUMMARY FOR SEMR IN C-130/135 AIRCRAFT* ($K, FY77)

MAINTENANCE CONCEPT	OPERATIONAL LIFE (YEARS)	LEVEL OF BITE				
		NO BITE	GROUP	8 TO 10	4 TO 6	INDIVIDUAL
THROW AWAY	10	36,698	52,880	34,217	33,855	34,080
	15	50,724	71,195	47,716	47,173	47,506
	20	64,756	89,512	61,215	60,490	60,934
BASE REPAIR	10	215,566	231,251	213,589	213,257	213,375
	15	302,667	321,826	299,848	299,350	299,521
	20	389,764	412,402	386,106	385,441	385,668
DEPOT REPAIR	10	36,115	52,422	33,421	33,486	33,599
	15	49,676	70,305	46,918	46,417	46,580
	20	63,236	88,189	60,016	59,345	59,564

*1900 AIRCRAFT AT 120 BASES, 71,606 FLIGHT HOURS/MONTH

TABLE 12. LOGISTIC SUPPORT COST SUMMARY FOR C-141 AIRCRAFT* ($K, FY77)

MAINTENANCE CONCEPT	OPERATIONAL LIFE (YEARS)	LEVEL OF BITE				
		NO BITE	GROUP	8 TO 10	4 TO 6	INDIVIDUAL
THROW AWAY	10	9,268	10,787	9,079	8,890	9,060
	15	12,460	14,383	12,206	11,922	12,172
	20	15,651	17,976	15,331	14,951	15,280
BASE REPAIR	10	22,947	23,982	21,794	21,605	21,750
	15	32,002	30,501	30,247	29,963	30,172
	20	41,053	39,017	38,699	38,320	38,594
DEPOT REPAIR	10	9,507	11,125	9,444	9,254	9,396
	15	12,655	14,700	12,563	12,278	12,485
	20	15,802	18,273	15,680	15,300	15,572

*265 AIRCRAFT AT 9 BASES, 21,426 FLIGHT HOURS/MONTH

TABLE 13. LOGISTIC SUPPORT COST SUMMARY FOR SEMR IN MIXED FORCE* ($K, FY77)

MAINTENANCE CONCEPT	OPERATIONAL LIFE (YEARS)	LEVEL OF BITE				
		NO BITE	GROUP	8 TO 10	4 TO 6	INDIVIDUAL
THROW AWAY	10	43,753	59,033	40,222	39,708	40,036
	15	60,281	79,887	56,183	55,411	55,898
	20	75,808	100,740	72,143	71,111	71,759
BASE REPAIR	10	233,189	243,707	225,949	225,463	225,673
	15	322,128	339,501	317,376	316,648	316,958
	20	415,063	435,296	408,803	407,832	408,240
DEPOT REPAIR	10	41,704	58,128	39,396	38,910	39,111
	15	57,516	78,302	54,718	53,987	54,286
	20	76,328	98,476	70,040	69,064	69,459

*2165 AIRCRAFT AT 125 BASES, 93,032 FLIGHT HOURS/MONTH

TABLE 14. AVERAGE UNIT PRODUCTION COST OF SEMR* ($K, FY77)

AIRCRAFT TYPE	QUANTITY	LEVEL OF BITE				
		INDIVIDUAL MODULE	4 TO 6 MODULES	8 TO 10 MODULES	GROUP	NO BITE
C-130/135	1900	109	102	100	100	96
C-141	265	125	116	114	114	111
MIXED FORCE	2165	104	98	96	96	92

*90% CUMULATIVE AVERAGE LEARNING CURVE ASSUMED

TABLE 15. SUMMARY OF LCC ESTIMATES FOR SEMR IN C-130/135 AIRCRAFT ($K, FY77)

MAINTENANCE CONCEPT	OPERATIONAL LIFE (YEARS)	LEVEL OF BITE				
		NO BITE	GROUP	8 TO 10	4 TO 6	INDIVIDUAL
THROW AWAY	10	243,867	267,649	248,986	252,424	265,949
	15	257,893	285,964	262,485	265,742	279,375
	20	271,925	304,281	275,984	279,059	292,803
BASE REPAIR	10	422,735	446,020	428,358	431,826	445,244
	15	509,836	536,595	514,617	517,919	531,390
	20	596,933	627,171	600,875	604,010	617,537
DEPOT REPAIR	10	243,284	267,191	248,190	252,055	265,468
	15	256,845	285,074	261,687	264,986	278,449
	20	270,405	302,958	274,785	277,914	291,433

TABLE 16. SUMMARY OF LCC ESTIMATES FOR SEMR IN C-141 AIRCRAFT ($K, FY77)

MAINTENANCE CONCEPT	OPERATIONAL LIFE (YEARS)	LEVEL OF BITE				
		NO BITE	GROUP	8 TO 10	4 TO 6	INDIVIDUAL
THROW AWAY	10	46,454	48,768	47,060	47,401	49,956
	15	49,646	52,364	50,187	50,433	53,068
	20	52,837	55,957	53,312	53,462	56,176
BASE REPAIR	10	60,133	59,963	59,775	60,116	62,646
	15	69,188	68,482	68,228	68,474	71,068
	20	78,239	76,998	76,680	76,831	79,490
DEPOT REPAIR	10	46,693	49,106	47,425	47,765	50,292
	15	49,841	52,681	50,544	50,789	53,381
	20	52,988	56,254	53,661	53,811	56,468

TABLE 17. SUMMARY OF LCC ESTIMATES FOR SEMR IN MIXED FORCE ($K, FY77)

MAINTENANCE CONCEPT	OPERATIONAL LIFE (YEARS)	LEVEL OF BITE				
		NO BITE	GROUP	8 TO 10	4 TO 6	INDIVIDUAL
THROW AWAY	10	270,522	294,462	275,651	279,467	292,785
	15	287,050	315,316	291,612	295,170	308,647
	20	302,577	336,169	307,572	310,870	324,508
BASE REPAIR	10	459,958	479,136	461,378	465,222	478,422
	15	548,897	574,930	552,805	556,407	569,707
	20	641,832	670,725	644,232	647,591	660,989
DEPOT REPAIR	10	268,473	293,557	274,825	278,669	291,860
	15	284,285	313,731	290,147	293,746	307,035
	20	300,097	333,905	305,469	308,823	322,208

radar functional areas are left intact. This permits accomplishment of equivalent tests using external test equipment. This equipment is estimated to be equal in complexity to the BITE subsystem but more costly. In use, the maintenance technician would connect the test equipment to the radar on the flight line and run a set of tests that are comparable to the BITE tests to isolate to 4 to 6 SEMs. He would then identify the faulty module by replacement. The maintenance concept is thus similar to the baseline case, but the test equipment is nonresident in the radar rather than being integral. Labor hours are increased to account for additional operations required.

Comparison of logistics support cost results for the no BITE case show that this is slightly more expensive than the baseline case. No BITE does result in slightly lower life cycle cost because the savings in unit acquisition cost more than offset the additional cost of test equipment per base. However, the differential is less than the accuracy of the model and is therefore inconclusive.

7.3 BITE TO FLU OR GROUP

The next case examined is that of a BITE subsystem which isolates only to a group or FLU. This would be removed and tested as an integral unit to fault isolate to a module. A separate set of test equipment and labor is required for testing as compared to the baseline case of BITE to 4 to 6 modules. However, the BITE subsystem is simplified.

Comparison of the logistic support cost results shows that group BITE is more expensive than the baseline. Life cycle cost is also generally greater. However, the amount of the differential is not great enough to definitely eliminate this concept.

7.4 BITE TO 8 TO 10 MODULES

For BITE to 8 to 10 modules the BITE subsystem is more complex than for group BITE but simpler than for BITE 4 to 6 modules. The number of test points sampled and the length of the program is decreased compared to BITE 4 to 6 modules, but the labor for module substitution to identify the faulty module is increased. Results show that logistic support costs are increased slightly, while total cost is decreased slightly. However, the differences are not large enough to be considered significant.

7.5 BITE TO AN INDIVIDUAL MODULE

For BITE to the individual module the number of test points, length of program and signal conditioning are increased by an approximate ratio of 4:1. However, the labor for module substitution is decreased. Comparison of results for individual module BITE versus BITE to 4 to 6 modules shows a small increase in logistics support cost. This occurs because the savings in labor of fault isolation are outweighed by the increase in failure rates and associated costs due to the additional hardware. Life cycle costs for individual module BITE versus BITE 4 to 6 modules are also higher. The increase in cost here is primarly due to the additional BITE hardware which is not offset by a savings in logistics support costs. Again it should be noted that the cost differences are small.

7.6 SUMMARY

The BITE cases examined do not show any large differences, except for the group BITE case in which an additional test and repair level for groups or FLUs results in somewhat higher logistics support costs. The no BITE case is similar to the BITE to 4 to 6 modules because it is assumed that the

testability of the radar is the same as for the baseline BITE system and that test equipment similar to that BITE system is used to perform the same testing.

If the radar is not designed to permit this maintenance approach, the repair method would be similar to that for group BITE, and costs would probably be higher than for the group BITE case. The data indicate that the most important factor is to design the system with built-in test points. The automatic fault isolation level chosen does not appear to be significant and indicates the range of 4 to 10 modules may be adequate.

SECTION VIII
MINIMUM LIFE CYCLE COST

In the baseline LSC Model runs, it is assumed that standard modules are always thrown away upon failure and that handling of special modules varies with the maintenance concept being examined, i.e., thrown away, repaired at the base, or repaired at the depot. This is in accordance with the support philosophy adopted by the Navy Standard Electronic Module Program (SEMP). Because it is not clear that any of the maintenance concepts examined yields minimum logistic support costs, a separate analysis was performed to determine the breakeven unit cost for throwaway vs. repair of SEMs used in SEMR.

LSC Model equations and SEMR input data were used to determine breakeven repair costs for individual SEM types under the same conditions as the baseline computer runs. Four of the 94 SEM types used in SEMR were found to have an average unit depot repair cost less than their replacement value. This indicated that the most economical repair concept would be to repair these and only these SEM types at the depot. LSC Model runs for this concept were then made to determine the amount of savings obtained, if this were done.

8.1 CONCLUSIONS

The curves shown in Figures 12 and 13 are based on weighted average SEM data and were used to determine which of the 94 SEM types used in SEMR should be examined more closely. Table 18 presents specific calculations of the breakeven cost for seven SEM types identified by the curve screening process. Actual life cycle cost savings afforded by repairing only these selected SEM types were then determined by computer cost runs with results shown in Table 19. Principal conclusions cf the analysis are:

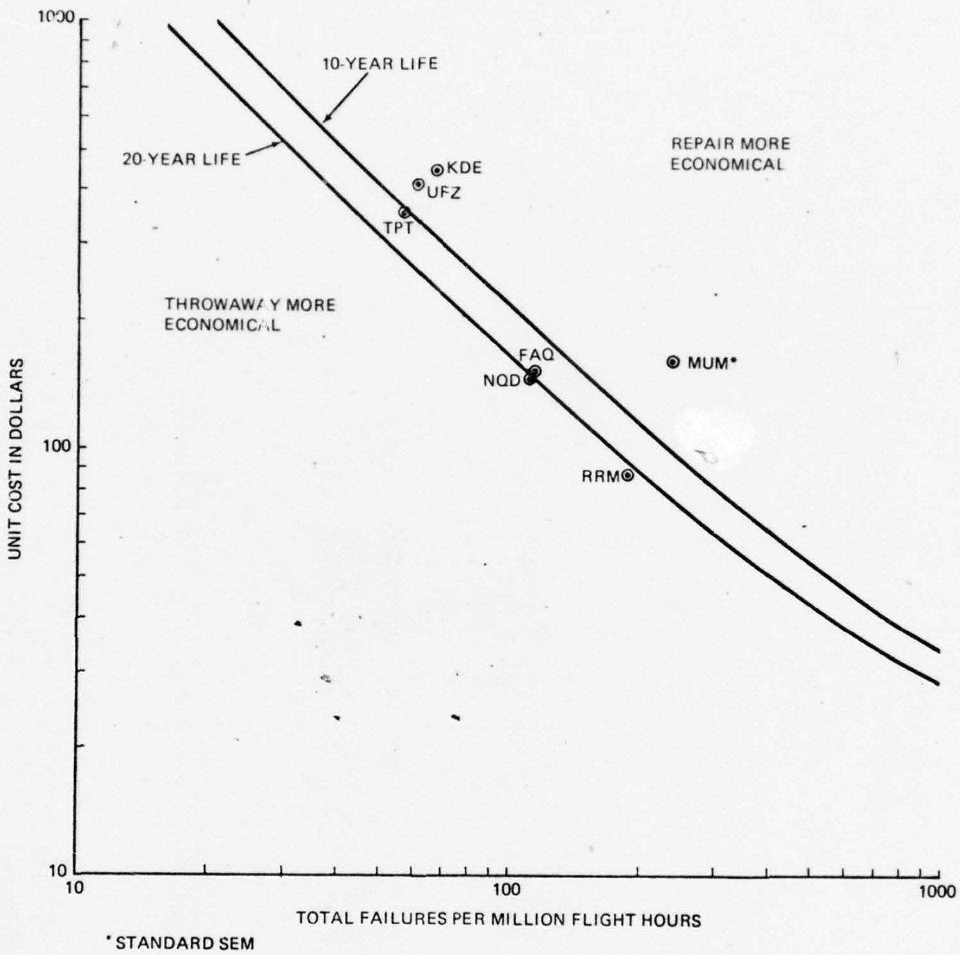

Figure 12. Optimum throwaway costs for SEMR SEMs depot repair - mixed force.

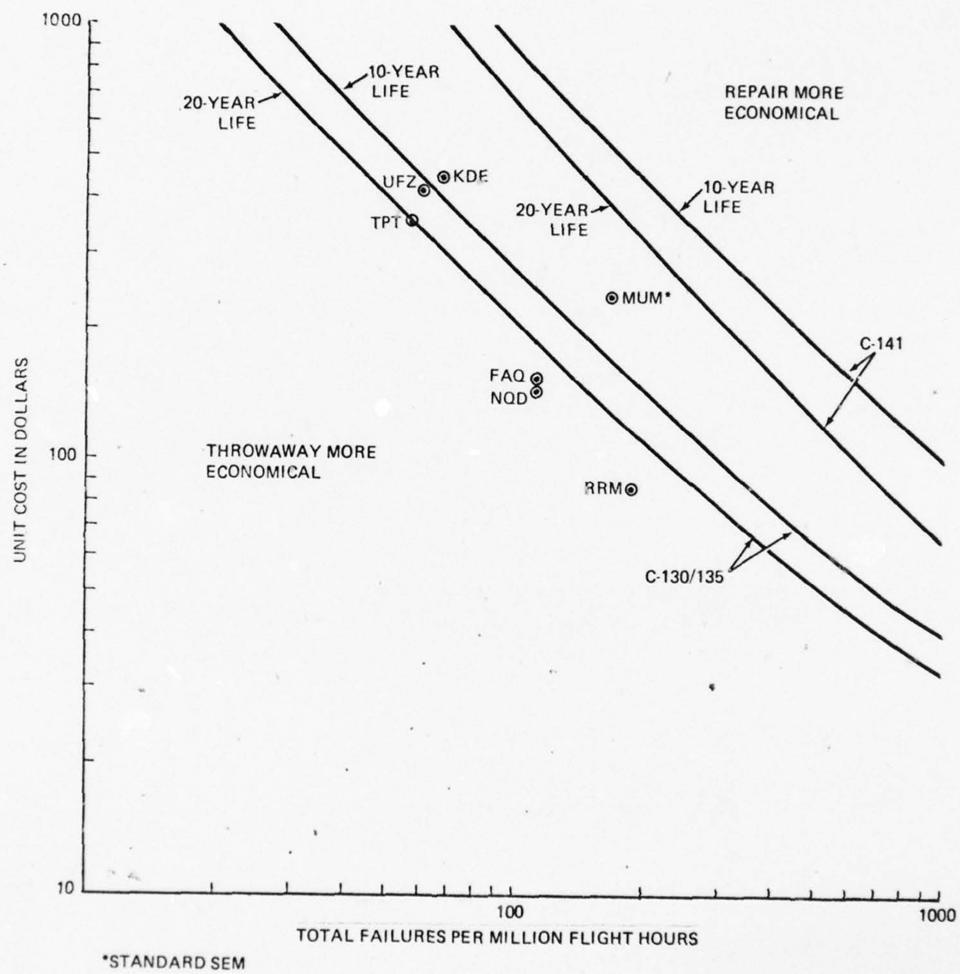

Figure 13. Optimum throwaway costs for SEMR SEMs depot repair - C-130/135 and C-141.

TABLE 18. MAXIMUM THROWAWAY COST FOR SELECT SEMs[1]

SEM TYPE	UNIT COST	MIXED FORCE		C-130/135		C-141	
		10 YEARS	20 YEARS	10 YEARS	20 YEARS	10 YEARS	20 YEARS
FAQ	$152	$197	$153	$252	$194	$810	$617
KDE	448	$\boxed{329}$	$\boxed{262}$	$\boxed{433}$	$\boxed{335}$	1415	1089
MUM	236	$\boxed{131}$	$\boxed{100}$	$\boxed{163}$	$\boxed{124}$	565	421
NQD	145	193	147	242	182	877	653
RRM	86	121	94	154	117	482	360
TPT[2]	356	371	$\boxed{283}$	480	363	1567	1178
UFZ[3]	414	$\boxed{353}$	$\boxed{271}$	456	$\boxed{347}$	1490	1130

1. REPAIR IS MORE ECONOMICAL FOR ANY CASE IN WHICH THE MAXIMUM THROWAWAY COST SHOWN IS LESS THAN THE ESTIMATED UNIT COST. ALL SEMs HAVING AN ESTIMATED UNIT COST LESS THAN 10% BELOW THE CALCULATED MAXIMUM ARE INCLUDED FOR COMPLETENESS.

2. MAXIMUM THROWAWAY COST FOR TYPE TPT SEM IN MIXED FORCE OVER 15-YEAR LIFE IS $312.

3. MAXIMUM THROWAWAY COST FOR TYPE UFZ SEM IN C-130/135 OVER 15-YEAR LIFE IS $383.

TABLE 19. SUMMARY OF SEMR LOGISTIC SUPPORT COSTS ($K, FY 77) (BASELINE CASE: BITE TO 4-6 MODULES)

AIRCRAFT TYPE	OPERATIONAL LIFE (YEARS)	MAINTENANCE CONCEPT			
		THROWAWAY	BASE REPAIR	DEPOT REPAIR	MIN COST
C-130/135	10	33,855	213,257	33,486	33,413
	15	47,173	299,350	46,417	46,276
	20	60,490	385,442	59,345	59,297
C-141	10	8,890	21,605	9,254	*
	15	11,922	29,963	12,278	*
	20	14,951	38,320	15,300	*
MIXED FORCE	10	39,708	225,463	38,910	38,638
	15	55,411	316,648	53,987	53,769
	20	71,111	407,832	69,064	69,048

*THROWAWAY IS LEAST COSTLY MAINTENANCE CONCEPT FOR C-141 CONFIGURATION.

a. Maximum throwaway cost is a function of total failures which is determined by number of a given type SEM used. This plus other system-peculiar inputs to the cost model make calculated throwaway cost highly sensitive to the particular system being analyzed. This is shown by the differences in calculated throwaway costs for the three SEMR cases analyzed, i.e., C-130/135, C-141, and mixed force.

b. Costs associated with establishing base repair facilities are so great that base repair of SEMs is never more economical than throwaway for any SEM used in SEMR.

c. For the C-141 case total failures are small enough (due to combination of relatively high reliability and small number of total flight hours) that savings afforded by repair do not offset the cost of establishing even a single depot repair facility. This holds even though the support equipment was assumed to be already in place.

d. Results for C-130/135 and mixed force cases are nearly the same because the C-130/135 version of SEMR dominates the mixed force (1900 of 2165 total aircraft and 77% of total flight hours).

e. Two SEM types (KDE and MUM) are more economical to repair over all life cycles in either the C-130/135 or mixed force case. Type UFZ is more economical to repair over all life cycles in the mixed force case but only over 15 or 20-year cycles in the C-130/135. Type TPT is more economical to repair over 15 or 20-year life cycles in the mixed force case but should be thrown away for all life cycles in the C-130/135 case (see Table 18).

f. Only three other SEM types (FAQ, NQD, and RRM) have an estimated unit cost within 10% of the computed maximum throwaway cost for any case.

g. Of the seven SEM types listed in Table 18 only MUM is a standard SEM.

h. The savings for the minimum cost case over either throwaway or depot repair are less than 1% in all cases. This is less than the expected accuracy of the estimate and is therefore considered insignificant.

8.2 ANALYSIS PROCEDURE

The analysis is based on the AFLC Logistic Support Cost Model which consists of eight basic equations for electronics systems. These have been broken out into two or three subequations each to isolate 21 separate cost elements for the SEMR Cost Analysis Program. These equations and definitions of the variables used are presented in Appendices B and C. Input values used for this analysis are tabulated in Tables 20 and 21. These are identical to the inputs used for the baseline computer runs. Note in Table 21 that some inputs change as a function of the repair concept.

Substitution of these inputs into the 21 subequations for the three repair concepts (throwaway, base repair, and depot repair) and combining the results yields the two sets of equations shown in Table 22. Variables retained in symbolic form in these equations are those which are functions of operational life, aircraft type, or the SEM itself. Substitution of correct values for all but the SEM-dependent variables and combining gives the resultant equations shown in Table 23. Similar sets were derived for 15 and 20-year life cycles but are not included herein.

TABLE 20. INPUT CONSTANT VALUES

CONSTANT*	VALUE	CONSTANT*	VALUE
BAA	168.	PA	0.
BCA	0.	PAMH	0.3
BLR	14.11	PFFH[1]	9.3×10^4
BMR	3.48	PFFH[2]	7.16×10^4
BPA	0.	PFFH[3]	2.14×10^4
BRCT	0.13	PMB	1.5×10^3
DAA	168.	PMD	1.5×10^3
DCA	0.	PSC	0.64
DLR	19.55	PSO	1.32
DMR	5.66	RIP	0.
DOWN	0.05	RMC	112.85
DPA	0.	RMH	1.0
DRCT	1.84	SA	39.63
EBO	0.1	SMH	0.
FB	0.	SMI	∞
FD	0.	SR	0.25
FLA	0.	STK	0.
IMC	50.47	TCB	8.0×10^3
M[1]	125.	TCD	8.0×10^3
M[2]	120.	TD	238.26
M[3]	9.	TE	0.
MRF	0.24	TFFH[1]	1.12×10^7
MRO	0.08	TFFH[2]	8.59×10^6
OS[1]	0.24	TFFH[3]	2.57×10^6
OS[2]	0.27	TR	0.16
OS[3]	0.	TRB	0.33
OSTCON	0.36	TRD	0.15
OSTOS	0.53	UF	1.2

Notes:
1. Values for mixed force analysis
2. Values for C-130/135 Analysis
3. Values for C-141 analysis
4. TFFH values are for 10-year life, for 15 or 20-year life cycles multiply by 1.5 or 2.0, respectively.

*See Appendix B for definitions

TABLE 21. INPUT VARIABLE VALUES

VARIABLE*	THROWAWAY	BASE REPAIR	DEPOT REPAIR
BCMH	0.	0.1	0.
BMH	0.	0.5	0.
BUR	0.	1.0	0.
CAB	0.	1.5×10^5	0.
CAD	0.	0.	1.0×10^5
COB	0.	0.1	0.
COD	0.	0.	0.1
COND	1.	0.	0.
CS	0.	5.0×10^3	5.0×10^3
DMH	0.	0.	0.5
DUR	0.	0.	0.5
H	0.	0.	3.
IH[1]	0.	6.25×10^4	5.0×10^2
IH[2]	0.	6.0×10^4	5.0×10^2
IH[3]	0.	4.5×10^3	5.0×10^2
JJ	0.	3.	0.
NRTS	0.	0.	1.
RTS	0.	1.	0.

Notes: 1. Values for mixed force analysis

2. Values for C-130/135 analysis

3. Values for C-141 analysis

*See Appendix B for definitions

TABLE 22. COST ELEMENT EQUATIONS

ELEMENT	BASE REPAIR VS THROWAWAY	DEPOT REPAIR VS THROWAWAY
C_{11}	0	0
C_{12}	0	1.84(PFFH)(F/H)(UC)
C_{13}	-(TFFH)(F/H)(UC)	-(TFFH)(F/H)(UC)
C_{21}	0	0
C_{22}	0	0
C_{31}	(TFFH)(F/H)[10.2+(BMC)(UC)]	0
C_{32}	0	(TFFH)(F/H)[12.6+(DMC)(UC)]
C_{33}	-(TFFH)(F/H)[0.864(1-QS)+1.78(QS)] x(w)	+(TFFH)(F/H)[0.864(1-QS)+1.78(QS)] x(w)
C_{41}	[50.47+112.85(PIUP)](PP)	[50.47+112.85(PIUP)](PP)
C_{42}	39.63(M)(PIUP)(PP+SP)	0
C_{51}	$[3.76 \times 10^{-3}(PFFH)(F/H)]^{*}[1+0.1(PIUP)] \times 1.5 \times 10^{5}$	0
C_{52}	0	$[6.27 \times 10^{-3}(PFFH)(F/H)]^{**}[1+0.1(PIUP)] \times 1 \times 10^{5}$
C_{53}	$5 \times 10^{3}+IH$	$5 \times 10^{3}+IH$
C_{61}	$\frac{10.13[1+0.33(PIUP-1)]}{PIUP}(TFFH)(F/H)$	0
C_{62}		$\frac{2.667[1+0.15(PIUP-1)]}{PIUP}(TFFH)(F/H)$
C_{63}	0	0
C_{71}	0	0
C_{72}	0	0
C_{73}	7.15×10^{2}	7.15×10^{2}
C_{81}	0	0
C_{82}	0	0

*Must be integer divisible by M
**Must be integer

TABLE 23. RESULTANT EQUATIONS FOR PIUP* = 10

1. Base Repair vs Throwaway

a. Mixed Force

$$1.12\times10^{7}(BMC-1)(F/H)(UC)+[1.59\times10^{8}-1.21\times10^{7}(w)](F/H)$$
$$+1.18\times10^{3}(PP)+4.95\times10^{4}(PP+SP)+3.76\times10^{7} = 0$$

b. C-130/135

$$8.59\times10^{6}(BMC-1)(F/H)(UC)+[1.22\times10^{8}-9.53\times10^{6}(w)](F/H)$$
$$+1.18\times10^{3}(PP)+4.75\times10^{4}(PP+SP)+3.61\times10^{7} = 0$$

c. C-141

$$2.57\times10^{6}(BMC-1)(F/H)(UC)+[3.65\times10^{7}-2.22\times10^{6}(w)](F/H)$$
$$+1.18\times10^{3}(PP)+3.56\times10^{3}(PP+SP)+2.71\times10^{6} = 0$$

2. Depot Repair vs Throwaway

a. Mixed Force

$$[1.12\times10^{7}(DMC-1)+1.71\times10^{5}](F/H)(UC)+[1.48\times10^{8}+1.21\times10^{7}(w)]$$
$$\times(F/H)+1.18\times10^{3}(PP)+2.06\times10^{5} = 0$$

b. C-130/135

$$[8.59\times10^{6}(DMC-1)+1.32\times10^{5}](F/H)(UC)+[1.13\times10^{8}+9.53\times10^{6}(w)]$$
$$\times(F/H)+1.18\times10^{3}(PP)+2.06\times10^{5} = 0$$

c. C-141

$$[2.57\times10^{6}(DMC-1)+3.93\times10^{4}](F/H)(UC)+[3.4\times10^{7}+2.22\times10^{6}(w)]$$
$$\times(F/H)+1.18\times10^{3}(PP)+2.06\times10^{5} = 0$$

*PIUP = Program Inventory Usage Period (i.e. operational life)

Table 24 presents the SEM-dependent data for all SEM types used in SEMR, and Table 25 gives weighted average values for the variables used in the equations of Table 23. Figures 12 and 13 present curves showing the breakeven (throwaway vs. repair) SEM unit cost as a function of total failures per million flight hours for SEMs used in SEMR. Only the depot repair option is shown because base repair was found to be uneconomical in all cases. All but the seven SEMR SEMs shown are clearly on the throwaway side of these curves. Since these curves are based on average SEM data, computations using individual SEM data were made for each of these seven types. This produced the results shown in Table 18.

8.3 LSC MODEL RUNS

Six LSC Model runs were made to determine the amount of LCC savings obtained by repairing only selected SEMs. Specific SEMs assumed to be repaired for each of these six cases are shown in Table 26. These and all non-SEM repairs were assumed to be performed at the depot with all other SEMs discarded upon failure. Results for these cases are presented in Table 19 together with those for the baseline cases.

Although a small savings is indicated in each case, the amount is so small (less than 1%) in relation to the expected accuracy of the estimate that it must be considered insignificant. Comparison of throwaway vs. depot repair* for the baseline cases shows similar results (i.e., savings less than 4% in all cases). Thus, the only conclusion that can be made on the basis of these results is that base repair is significantly more costly than any of the other maintenance concepts considered.

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*In the depot repair concept standard modules are assumed to be discarded upon failure and special modules are returned to depot for repair.

TABLE 24. SEM COST AND FAILURE RATE DATA

KEY CODE	TYPE	SIZE	W[1]	QPA[2]	$\lambda(\times 10^{-6})$	F/H[4]	UC[5]	BMC/DMC[6]	PP/SP[7]
ADL	STD	1A	0.1	15/14	0.60	10.63	60.	*	*
AEA	SPEC	1A	0.1	1	4.50	5.40	92.	0.01	16
AEC	SPEC	1A	0.1	3	3.71	13.36	73.	0.01	20
AEH	NS	1A	0.1	4	15.00	72.00	136.	**	**
AFD	SPEC	1A	0.1	1	1.51	1.81	145.	0.02	8
BBA	STD	1A	0.1	1	2.15	2.58	75.	*	*
BDL	STD	1A	0.1	14	2.32	38.98	47.	*	*
BED	STD	1A	0.1	2	4.50	10.80	124.	*	*
CDJ	SPEC	1B	0.2	2	3.35	8.04	112.	0.01	7
CED	SPEC	1A	0.1	3	9.47	34.09	123.	0.02	13
CFF	SPEC	1A	0.1	1	7.80	9.36	105.	0.02	11
CFG	SPEC	1B	0.2	1	7.14	8.57	142.	0.01	27
CGK	SPEC	1B	0.2	1	5.22	6.26	144.	0.02	17
CGL	NS	1B	0.2	6	6.20	44.64	158.	**	**
CMH	STD	1A	0.1	14	1.02	17.14	41.	*	*
DPR	SPEC	1G	0.7	3	5.28	19.01	322.	0.01	22
D2F	SPEC	1A	0.1	1	7.58	9.10	124.	0.04	4
D2G	SPEC	1A	0.1	1	7.58	9.10	124.	0.04	4
EAB	SPEC	1A	0.1	1	0.52	0.62	76.	0.03	2
EEC	SPEC	1A	0.1	1	1.20	1.44	87.	0.02	6
EGA	NS	1A	0.1	4	0.60	2.88	111.	**	**
EHP	SPEC	1A	0.1	1	2.80	3.36	78.	0.01	17
EHR	SPEC	1A	0.1	1	3.56	4.27	100.	0.02	13
EPM	SPEC	1B	0.2	3	20.39	73.40	110.	0.04	3
FAQ	NS	1B	0.2	5	18.73	112.38	152.	**	**
FAR	NS	1B	0.2	4	9.51	45.65	129.	**	**
FEG	SPEC	1B	0.2	3	9.06	32.62	143.	0.01	19
FEH	SPEC	1A	0.1	1	2.23	2.68	89.	0.02	14
FFE	NS	1C	0.3	12	5.23	75.31	180.	**	**
FHA	STD	1A	0.1	7	2.35	19.74	198.	*	*
GAE	NS	1B	0.2	5	1.22	7.32	91.	**	**
GAF	SPEC	1C	0.3	3	6.69	24.08	169.	0.01	14
GBD	SPEC	1A	0.1	3/2	2.31	7.68	84.	0.01	14
GDJ	STD	1A	0.1	10/8	2.61	29.88	52.	*	*
GDM	STD	1A	0.1	2/1	2.58	5.48	129.	*	*
GDN	STD	1A	0.1	1	2.39	2.87	45.	*	*
GEE	STD	1A	0.1	2	3.63	8.71	146.	*	*
GVQ	STD	1A	0.1	2	0.71	1.70	55.	*	*
GZB	SPEC	1A	0.1	2	2.29	5.50	87.	0.03	4
HRH	STD	1A	0.1	1	23.20	27.84	350.	*	*
JDB	STD	1A	0.1	4	2.71	13.01	52.	*	*
KDE	SPEC	2B	0.4	1	55.49	66.59	448.	0.01	47
KDQ	STD	1A	0.1	7/5	3.50	27.47	73.	*	*
KDR	STD	1A	0.1	8/7	2.04	19.02	33.	*	*
KLQ	SPEC	1G	0.7	1	4.24	5.09	177.	0.01	11
LDN	STD	1A	0.1	1	1.53	1.84	29.	*	*
LDQ	STD	1A	0.1	14	1.80	30.24	31.	*	*
MUM	STD	1A	0.1	21/19	6.60	162.68	236.	*	*
NQD	NS	1A	0.1	17/15	5.50	109.16	145.	**	**
PFB	NS	1C	0.3	11	5.71	75.37	165.	**	**
PQD	SPEC	1A	0.1	2	3.28	7.87	100.	0.04	6
RAD	SPEC	1A	0.1	1	8.80	10.56	77.	0.02	7
RBA	SPEC	1B	0.2	3	6.36	22.90	161.	0.01	28
RBB	SPEC	1A	0.1	1	2.77	3.32	84.	0.01	22
RBF	STD	1A	0.1	12	1.21	17.42	95.	*	*

TABLE 24. SEM COST AND FAILURE RATE DATA (CONTINUED)

KEY CODE	TYPE	SIZE	w[1]	QPA[2]	$\lambda(x10^{-6})$	F/H[4]	UC[5]	BMC/DMC[6]	PP/SP[7]
REC	NS	1A	0.1	6	5.25	37.80	127.	**	**
RRM	SPEC	1A	0.1	15	10.22	183.96	86.	0.04	5
SHU	STD	1A	0.1	2/1	4.64	9.86	310.	*	*
SHV	STD	1A	0.1	2/1	7.44	15.80	340.	*	*
SHX	STD	1B	0.2	2/1	7.44	15.80	380.	*	*
SHY	STD	1A	0.1	2/1	6.00	13.52	370.	*	*
SQS	SPEC	1A	0.1	1	3.19	3.83	151.	0.04	8
TEZ	SPEC	1B	0.2	2	21.43	51.43	207.	0.01	21
TPT	SPEC	2G	1.4	2	23.21	55.70	356.	0.01	18
UET	SPEC	1B	0.2	1	1.30	1.56	137.	0.01	5
UFS	SPEC	1A	0.1	2	7.31	17.54	121.	0.02	16
UFZ	SPEC	2B	0.4	1	50.13	60.16	414.	0.01	28
UGW	NS	1A	0.1	4	4.87	23.38	105.	**	**
UMU	NS	1A	0.1	4	4.36	20.93	169.	**	**
VBS	SPEC	1B	0.2	1	5.87	7.04	132.	0.01	15
VEW	SPEC	1A	0.1	2	3.33	7.99	112.	0.02	11
VFT	SPEC	1A	0.1	1	4.98	5.98	84.	0.01	18
VHU	SPEC	1B	0.2	1	2.42	2.90	234.	0.01	12
VJX	SPEC	1A	0.1	1	0.77	0.92	75.	0.01	10
VLY	SPEC	1A	0.1	1	1.42	1.70	81.	0.02	10
WET	SPEC	1A	0.1	1	6.21	7.45	74.	0.02	7
WHV	SPEC	2B	0.4	1	42.37	50.84	300.	0.01	44
WHW	SPEC	1A	0.1	1	6.18	7.42	93.	0.02	9
WKX	SPEC	1A	0.1	1/0	2.91	2.69	83.	0.01	3
WRU	SPEC	1B	0.2	1	2.41	2.89	155.	0.03	4
WSY	SPEC	1B	0.2	2	4.41	10.58	126.	0.02	4
WXZ	SPEC	1B	0.2	1	10.48	12.58	140.	0.01	14
XEV	SPEC	1A	0.1	1	0.56	0.67	68.	0.01	4
XFW	SPEC	1A	0.1	1	0.89	1.07	99.	0.01	14
XJX	SPEC	1A	0.1	1	9.64	11.57	64.	0.01	7
XKY	SPEC	1A	0.1	1	1.89	2.27	75.	0.01	8
XPU	SPEC	2G	1.4	1	29.76	35.71	358.	0.01	12
XYS	SPEC	1A	0.1	2	10.69	25.66	160.	0.05	5
YBZ	STD	1A	0.1	8	2.29	21.98	94.	*	*
YEW	SPEC	1A	0.1	1	6.93	8.32	69.	0.01	7
YPZ	SPEC	1D	0.4	1	16.61	19.93	195.	0.01	22
ZBW	SPEC	1A	0.1	2/1	2.77	5.88	113.	0.06	4
9206	SPEC	1C	0.3	2/1	1.28	2.72	250.	0.03	5
U2X	SPEC	1A	0.1	2/0	33.59	62.07	117.	0.04	5

Notes:

1. Weight in pounds of a single SEM.
2. Number of SEMs per system. (x/x notation indicates quantities used in C-130/135 and C-141 versions, respectively, single number indicates same quantity used in both versions.)
3. Predicted number of failures per million operating hours for a single SEM.
4. F/H = 1.2 λ (QPA), where 1.2 is assumed ratio of operating hours to flight hours. Values shown are for mixed force case with QPA weighted in accordance with number of aircraft of each type in force.
5. Unit cost in dollars.
6. Average material cost per repair expressed as fraction of unit cost.
7. Number of unique parts per SEM to be stocked for repair.

*Standard SEM (not repaired and component parts not stocked).

**Assumed new standard SEM qualified during SEMR development and treated in same manner as existing standard.

TABLE 25. AVERAGE VALUES FOR SEM INPUT VARIABLES[1]

Variable	Mixed Force	C-130/135	C-141
BMC	0.0221	0.0222	0.0216
DMC	0.0221	0.0222	0.0216
PP[2]	7.25	7.3	6.9
SP	14.5	14.6	13.8
W	0.208	0.207	0.212

Notes: 1. Only special SEMs included. Value weighted in accordance with quantities used and in mixed force case in accordance with number of aircraft of each type.

2. 50% of SEM components assumed to be already in government supply system.

TABLE 26. SEM TYPES ASSUMED TO BE REPAIRED IN MINIMUM COST CASES

AIRCRAFT TYPE	OPERATIONAL LIFE		
	10 YEARS	15 YEARS	20 YEARS
C-130/135	KDE MUM	KDE MUM UFZ	KDE MUM UFZ
MIXED FORCE	KDE MUM UFZ	KDE MUM UFZ TPT	KDE MUM UFZ TPT

8.4 GENERALIZATION OF RESULTS

A prime objective of the minimum cost analysis was to determine whether a simple "rule-of-thumb" could be formulated for use in making throwaway vs. repair decisions for individual SEM types. However, the results show that this is not possible. Still, the fact that the savings obtained by repairing selected SEM types (vs. throwaway of all failures) generally amounts to less than $100/system per year suggests that a simple policy of throwaway for all SEMs would be worth considering. Resulting larger quantity buys would tend to reduce unit costs (a factor not included in the analysis) thus reducing or eliminating the small cost advantage shown in the computation.

The fact that throwaway is always more economical for the C-141 shows that some minimum number of failures must be experienced before repair becomes worth while. This is substantiated in the C-130/135 and mixed force cases by the switch-over from throwaway to repair for one additional SEM type at the 15-year life point. Also, comparing the 15 and 20-year results* for throwaway and minimum cost in these cases shows that the amount of savings obtained by SEM repair increases with number of failures. However, the number of flight hours required to produce these small savings is very large (i.e., 12 to 17 million for the C-130/135 and 16 to 22 million for the mixed force).

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*10-year results cannot be included in this comparison because of the difference in SEM types being repaired.

APPENDIX A
COMPLETE LSC MODEL RESULTS

TABLE A-1. SEMR LOGISTIC SUPPORT COST SUMMARY ($K, FY 77)
(C-130/135 Configuration* With BITE to 4-6 Modules)

COST ELEMENT	THROWAWAY			BASE REPAIR			DEPOT REPAIR		
	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS
COST OF FLU SPARES	8,843	10,372	11,900	2,992	3,718	4,444	7,258	7,984	8,709
COST OF ON EQUIPMENT MAINTENANCE	948	1,422	1,896	948	1,422	1,896	948	1,422	1,896
COST OF OFF-EQUIPMENT MAINTENANCE	12,274	18,411	24,548	10,940	16,410	21,880	12,425	18,638	24,850
INVENTORY MANAGEMENT COST	9,608	14,397	19,186	127,432	191,121	254,809	12,207	15,283	20,359
COST OF SUPPORT EQUIPMENT	1,402	1,505	1,608	69,930	85,290	100,650	1,821	1,974	2,127
COST OF PERSONNEL TRAINING	164	184	204	358	465	572	170	192	214
COST OF MANAGEMENT AND TECHNICAL DATA	616	882	1,148	657	924	1,190	657	924	1,190
COST OF FACILITIES	0	0	0	0	0	0	0	0	0
TOTAL LOGISTIC SUPPORT COST	33,855	47,173	60,490	213,257	299,350	385,441	33,486	46,417	59,345

*1900 AIRCRAFT, 120 BASES, 71,606 FLIGHT HOURS/MONTH

TABLE A-2. SEMR LOGISTIC SUPPORT COST SUMMARY ($K, FY 77)
(C-141 Configuration* With BITE to 4-6 Modules)

COST ELEMENT	THROWAWAY			BASE REPAIR			DEPOT REPAIR		
	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS
COST OF FLU SPARES	2,634	3,208	3,782	914	1,179	1,444	2,023	2,288	2,553
COST OF ON-EQUIPMENT MAINTENANCE	236	355	473	236	355	473	236	355	473
COST OF OFF-EQUIPMENT MAINTENANCE	3,161	4,742	6,322	2,942	4,414	5,885	3,202	4,803	6,404
INVENTORY MANAGEMENT COST	1,296	1,930	2,563	10,570	15,828	21,086	1,881	2,796	3,709
COST OF SUPPORT EQUIPMENT	1,217	1,270	1,323	6,509	7,661	8,813	1,525	1,578	1,631
COST OF PERSONNEL TRAINING	130	134	139	178	204	230	131	136	141
COST OF MANAGEMENT AND TECHNICAL DATA	216	283	349	256	322	389	256	322	389
COST OF FACILITIES	0	0	0	0	0	0	0	0	0
TOTAL LOGISTIC SUPPORT COST	8,890	11,922	14,951	21,605	29,963	38,320	9,254	12,278	15,300

*265 AIRCRAFT, 9 BASES, 21,426 FLIGHT HOURS/MONTH

TABLE A-3. SEMR LOGISTIC SUPPORT COST SUMMARY ($K, FY 77)
(Mixed Force Configuration with BITE to 4-6 Modules)

COST ELEMENT	THROWAWAY			BASE REPAIR			DEPOT REPAIR		
	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS
COST OF FLU SPARES	10,571	12,484	14,398	3,593	4,496	5,400	8,575	9,477	10,381
COST OF ON-EQUIPMENT MAINTENANCE	1,184	1,777	2,369	1,184	1,777	2,369	1,184	1,777	2,369
COST OF OFF-EQUIPMENT MAINTENANCE	15,435	23,153	30,870	13,882	20,823	27,765	15,627	23,441	31,255
INVENTORY MANAGEMENT COST	9,966	14,935	19,903	132,617	198,900	265,180	10,565	15,821	21,076
COST OF SUPPORT EQUIPMENT	1,545	1,698	1,851	72,857	88,856	104,857	1,864	2,017	2,170
COST OF PERSONNEL TRAINING	174	199	223	417	550	683	182	208	235
COST OF MANAGEMENT AND TECHNICAL DATA	832	1,165	1,497	913	1,246	1,578	913	1,246	1,578
COST OF FACILITIES	0	0	0	0	0	0	0	0	0
TOTAL LOGISTIC SUPPORT COST	39,708	55,411	71,111	225,463	316,648	407,832	38,910	53,987	69,064

*2165 AIRCRAFT, 125 BASES' 93,032 FLIGHT HOURS

TABLE A-4. SEMR LOGISTIC SUPPORT COST SUMMARY ($K, FY 77)
(C-130/135 Configuration* with No BITE)

COST ELEMENT	THROWAWAY			BASE REPAIR			DEPOT REPAIR		
	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS
COST OF FLU SPARES	8,814	10,361	11,909	2,933	3,635	4,337	7,140	7,842	8,544
COST OF ON-EQUIPMENT MAINTENANCE	1,718	2,577	3,437	1,718	2,577	3,437	1,718	2,577	3,437
COST OF OFF-EQUIPMENT MAINTENANCE	12,173	18,260	24,346	16,235	24,353	32,471	12,291	18,437	24,583
INVENTORY MANAGEMENT COST	8,290	12,421	16,551	121,418	182,102	242,784	8,853	13,255	17,655
COST OF SUPPORT EQUIPMENT	4,499	5,398	6,295	71,847	88,003	104,158	4,869	5,817	6,766
COST OF PERSONNEL TRAINING	156	176	195	332	431	529	161	182	203
COST OF MANAGEMENT AND TECHNICAL DATA	1,048	1,531	2,013	1,083	1,566	2,048	1,083	1,566	2,048
COST OF FACILITIES	0	0	0	0	0	0	0	0	0
TOTAL LOGISTIC SUPPORT COST	36,698	50,724	64,756	215,566	302,667	389,764	36,115	49,676	63,236

*1900 AIRCRAFT, 120 BASES, 71,606 FLIGHT HOURS/MONTH

TABLE A-5. SEMR LOGISTIC SUPPORT COST SUMMARY ($K, FY 77)
(C-141 Configuration* with No BITE)

COST ELEMENT	THROWAWAY			BASE REPAIR			DEPOT REPAIR		
	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS
COST OF FLU SPARES	2,639	3,220	3,802	888	1,146	1,403	1,995	2,253	2,510
COST OF ON EQUIPMENT MAINTENANCE	434	651	867	434	651	867	434	651	867
COST OF OFF-EQUIPMENT MAINTENANCE	3,152	4,728	6,303	4,389	6,583	8,777	3,183	4,774	6,366
INVENTORY MANAGEMENT COST	1,191	1,773	2,355	10,110	15,140	20,169	1,743	2,589	3,435
COST OF SUPPORT EQUIPMENT	1,401	1,510	1,620	6,596	7,805	9,014	1,665	1,774	1,884
COST OF PERSONNEL TRAINING	124	129	133	169	194	218	126	131	135
COST OF MANAGEMENT AND TECHNICAL DATA	327	449	571	361	483	605	361	483	605
COST OF FACILITIES	0	0	0	0	0	0	0	0	0
TOTAL LOGISTIC SUPPORT COST	9,268	12,460	15,651	22,947	32,002	41,053	9,507	12,655	15,802

*265 AIRCRAFT, 9 BASES, 21,426 FLIGHT HOURS/MONTH

TABLE A-6. SEMR LOGISTIC SUPPORT COST SUMMARY ($K, FY 77)
(Mixed Force Configuration* with No BITE)

COST ELEMENT	THROWAWAY			BASE REPAIR			DEPOT REPAIR		
	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS
COST OF FLU SPARES	10,545	12,483	14,421	3,516	4,391	5,265	8,439	9,314	10,188
COST OF ON EQUIPMENT MAINTENANCE	2,152	3,228	4,305	2,152	3,228	4,305	2,152	3,228	4,305
COST OF OFF-EQUIPMENT MAINTENANCE	15,325	22,987	30,649	20,624	30,936	41,248	15,474	23,211	30,949
INVENTORY MANAGEMENT COST	9,605	13,893	17,181	130,381	189,547	252,711	9,168	13,727	18,285
COST OF SUPPORT EQUIPMENT	4,585	5,520	6,454	74,685	91,466	108,248	4,855	5,789	6,724
COST OF PERSONNEL TRAINING	166	190	214	387	511	633	172	198	224
COST OF MANAGEMENT AND TECHNICAL DATA	1,375	1,980	2,584	1,444	2,049	2,653	1,444	2,049	2,653
COST OF FACILITIES	0	0	0	0	0	0	0	0	0
TOTAL LOGISTIC SUPPORT COST	43,753	60,281	75,808	233,189	322,128	415,063	41,704	57,516	73,328

*2165 AIRCRAFT, 125 BASES, 93,032 FLIGHT HOURS/MONTH

TABLE A-7. SEMR LOGISTIC SUPPORT COST SUMMARY ($K, FY 77)
(C-130/135 Configuration* with Group BITE)

COST ELEMENT	THROWAWAY			BASE REPAIR			DEPOT REPAIR		
	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS
COST OF FLU SPARES	9,029	10,650	12,272	3,073	3,840	4,607	7,375	8,159	8,944
COST OF ON EQUIPMENT MAINTENANCE	921	1,381	1,842	921	1,381	1,842	921	1,381	1,842
COST OF OFF EQUIPMENT MAINTENANCE	12,628	18,942	25,256	11,284	16,925	22,567	12,767	19,150	25,533
INVENTORY MANAGEMENT COST	9,559	14,324	19,089	126,472	189,682	252,891	10,151	15,200	20,248
COST OF SUPPORT EQUIPMENT	19,462	24,080	28,698	87,990	107,865	127,740	19,881	24,549	29,217
COST OF PERSONNEL TRAINING	163	183	203	352	457	562	168	190	212
COST OF MANAGEMENT AND TECHNICAL DATA	1,118	1,635	2,152	1,159	1,676	2,193	1,159	1,676	2,193
COST OF FACILITIES	0	0	0	0	0	0	0	0	0
TOTAL LOGISTIC SUPPORT COST	52,880	71,195	89,512	231,251	321,826	412,402	52,422	70,305	88,189

*1900 AIRCRAFT, 120 BASES, 71,606 FLIGHT HOURS/MONTH

TABLE A-8. SEMR LOGISTIC SUPPORT COST SUMMARY ($K, FY 77)
(C-141 Configuration* with Group BITE)

COST ELEMENT	THROWAWAY			BASE REPAIR			DEPOT REPAIR		
	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS
COST OF FLU SPARES	2,794	3,447	4,101	1,059	1,396	1,733	2,168	2,505	2,842
COST OF ON EQUIPMENT MAINTENANCE	228	343	457	228	343	457	228	343	457
COST OF OFF EQUIPMENT MAINTENANCE	3,249	4,874	6,498	3,027	4,541	6,054	3,286	4,929	6,573
INVENTORY MANAGEMENT COST	1,291	1,923	2,554	10,490	15,709	20,927	1,869	2,778	3,666
COST OF SUPPORT EQUIPMENT	2,757	3,195	3,632	6,623	7,803	8,984	3,065	3,503	3,940
COST OF PERSONNEL TRAINING	128	132	137	175	201	226	129	134	139
COST OF MANAGEMENT AND TECHNICAL DATA	340	469	597	380	508	636	380	508	636
COST OF FACILITIES	0	0	0	0	0	0	0	0	0
TOTAL LOGISTIC SUPPORT COST	10,787	14,383	17,976	21,982	30,501	39,017	11,125	14,700	18,273

*265 AIRCRAFT, 9 BASES, 21,426 FLIGHT HOURS/MONTH

TABLE A-9. SEMR LOGISTIC SUPPORT COST SUMMARY ($K, FY 77)
(Mixed Force Configuration* with Group BITE)

COST ELEMENT	THROWAWAY			BASE REPAIR			DEPOT REPAIR		
	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS
COST OF FLU SPARES	10,868	12,931	14,993	3,813	4,826	5,839	8,794	9,807	10,820
COST OF ON-EQUIPMENT MAINTENANCE	1,149	1,724	2,299	1,149	1,724	2,299	1,149	1,724	2,299
COST OF OFF-EQUIPMENT MAINTENANCE	15,877	23,815	31,754	14,311	21,466	28,621	16,053	24,080	32,106
INVENTORY MANAGEMENT COST	9,912	14,855	19,796	131,578	197,341	263,103	10,498	15,720	20,942
COST OF SUPPORT EQUIPMENT	19,596	24,262	28,927	90,908	111,421	131,933	19,915	24,581	29,246
COST OF PERSONNEL TRAINING	173	197	222	409	539	670	180	206	233
COST OF MANAGEMENT AND TECHNICAL DATA	1,458	2,103	2,749	1,539	2,184	2,830	1,539	2,184	2,830
COST OF FACILITIES	0	0	0	0	0	0	0	0	0
TOTAL LOGISTIC SUPPORT COST	59,033	79,887	100,740	243,707	339,501	435,296	58,128	78,302	98,476

*2165 AIRCRAFT, 125 BASES, 93,032 FLIGHT HOURS/MONTH

TABLE A-10. SEMR LOGISTIC SUPPORT COST SUMMARY ($K, FY 77)
(C-130/135 Configuration* with BITE to 8-10 Modules)

COST ELEMENT	THROWAWAY			BASE REPAIR			DEPOT REPAIR		
	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS
COST OF FLU SPARES	8,956	10,541	12,126	3,085	3,858	4,631	6,951	8,124	8,897
COST OF ON-EQUIPMENT MAINTENANCE	1,209	1,813	2,418	1,209	1,813	2,418	1,209	1,813	2,418
COST OF OFF-EQUIPMENT MAINTENANCE	12,274	18,411	24,547	10,933	16,399	21,865	12,417	18,625	24,833
INVENTORY MANAGEMENT COST	9,608	14,397	19,186	127,432	191,121	254,809	10,207	15,283	20,359
COST OF SUPPORT EQUIPMENT	1,402	1,505	1,608	69,930	85,290	100,650	1,821	1,974	2,127
COST OF PERSONNEL TRAINING	162	182	202	353	459	564	169	191	213
COST OF MANAGEMENT AND TECHNICAL DATA	606	867	1,128	647	908	1,169	647	908	1,169
COST OF FACILITIES	0	0	0	0	0	0	0	0	0
TOTAL LOGISTIC SUPPORT COST	34,217	47,716	61,215	213,589	299,848	386,106	33,421	46,918	60,016

*1900 AIRCRAFT, 120 BASES, 71,606 FLIGHT HOURS/MONTH

TABLE A-11. SEMR LOGISTIC SUPPORT COST SUMMARY ($K, FY 77)
(C-141 Configuration* with BITE to 8-10 Modules)

COST ELEMENT	THROWAWAY			BASE REPAIR			DEPOT REPAIR		
	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS
COST OF FLU SPARES	2,764	3,403	4,042	1,047	1,379	1,710	2,156	2,488	2,819
COST OF ON-EQUIPMENT MAINTENANCE	300	451	601	300	451	601	300	451	601
COST OF OFF-EQUIPMENT MAINTENANCE	3,161	4,742	6,322	2,940	4,410	5,880	3,200	4,799	6,399
INVENTORY MANAGEMENT COST	1,296	1,930	2,563	10,570	15,828	21,086	1,881	2,795	3,709
COST OF SUPPORT EQUIPMENT	1,217	1,270	1,323	6,509	7,660	8,812	1,525	1,578	1,630
COST OF PERSONNEL TRAINING	128	132	137	175	201	227	129	134	139
COST OF MANAGEMENT AND TECHNICAL DATA	213	278	343	253	318	383	253	318	383
COST OF FACILITIES	0	0	0	0	0	0	0	0	0
TOTAL LOGISTIC SUPPORT COST	9,079	12,206	15,331	21,794	30,247	38,699	9,444	12,563	15,680

*265 AIRCRAFT, 9 BASES, 21,426 FLIGHT HOURS/MONTH

TABLE A-12. SEMR LOGISTIC SUPPORT COST SUMMARY ($K, FY 77)
(Mixed Force Configuration* with BITE to 8-10 Modules)

COST ELEMENT	THROWAWAY			BASE REPAIR			DEPOT REPAIR		
	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS
COST OF FLU SPARES	10,776	12,792	14,808	3,782	4,779	5,777	8,763	9,760	10,758
COST OF ON-EQUIPMENT MAINTENANCE	1,509	2,264	3,019	1,509	2,264	3,019	1,509	2,264	3,019
COST OF OFF-EQUIPMENT MAINTENANCE	15,435	23,152	30,870	13,873	20,809	27,746	15,616	23,424	31,232
INVENTORY MANAGEMENT COST	9,966	14,935	19,903	132,617	198,900	265,180	10,565	15,821	21,076
COST OF SUPPORT EQUIPMENT	1,545	1,698	1,851	72,857	88,856	104,856	1,864	2,017	2,170
COST OF PERSONNEL TRAINING	172	197	221	411	542	673	179	206	233
COST OF MANAGEMENT AND TECHNICAL DATA	819	1,145	1,471	900	1,226	1,552	900	1,226	1,552
COST OF FACILITIES	0	0	0	0	0	0	0	0	0
TOTAL LOGISTIC SUPPORT COST	40,222	56,183	72,143	225,949	317,376	408,803	39,396	54,718	70,040

*2165 AIRCRAFT, 125 BASES, 93,032 FLIGHT HOURS/MONTH

TABLE A-13. SEMR LOGISTIC SUPPORT COST SUMMARY ($K, FY 77)
(C-130/135 Configuration* with BITE to Individual Modules)

COST ELEMENT	THROWAWAY			BASE REPAIR			DEPOT REPAIR		
	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS
COST OF FLU SPARES	9,148	10,828	12,509	3,137	3,936	4,735	7,403	8,202	9,001
COST OF ON-EQUIPMENT MAINTENANCE	819	1,228	1,638	819	1,228	1,638	819	1,228	1,638
COST OF OFF-EQUIPMENT MAINTENANCE	12,274	18,411	24,549	10,977	16,466	21,955	12,470	18,705	24,940
INVENTORY MANAGEMENT COST	9,608	14,397	19,186	127,432	191,121	254,809	10,207	15,283	20,359
COST OF SUPPORT EQUIPMENT	1,402	1,505	1,608	69,930	85,290	100,650	1,821	1,974	2,127
COST OF PERSONNEL TRAINING	171	191	211	380	493	606	179	201	224
COST OF MANAGEMENT AND TECHNICAL DATA	658	946	1,233	700	987	1,275	700	987	1,275
COST OF FACILITIES	0	0	0	0	0	0	0	0	0
TOTAL LOGISTIC SUPPORT COST	34,080	47,506	60,934	213,375	299,521	385,668	33,599	46,580	59,564

*1900 AIRCRAFT, 120 BASES 71,606 FLIGHT HOURS/MONTH

TABLE A-14. SEMR LOGISTIC SUPPORT COST SUMMARY ($K, FY 77)
(C-141 Configuration* with BITE to Individual Modules)

COST ELEMENT	THROWAWAY			BASE REPAIR			DEPOT REPAIR		
	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS
COST OF FLU SPARES	2,821	3,489	4,156	1,059	1,397	1,734	2,168	2,506	2,843
COST OF ON-EQUIPMENT MAINTENANCE	197	295	393	197	295	393	197	295	393
COST OF OFF-EQUIPMENT MAINTENANCE	3,161	4,742	6,323	2,954	4,430	5,907	3,215	4,823	6,431
INVENTORY MANAGEMENT COST	1,296	1,930	2,563	10,570	15,828	21,086	1,881	2,796	3,709
COST OF SUPPORT EQUIPMENT	1,217	1,270	1,323	6,509	7,661	8,812	1,525	1,578	1,631
COST OF PERSONNEL TRAINING	139	144	148	192	220	248	141	146	151
COST OF MANAGEMENT AND TECHNICAL DATA	229	302	374	269	341	414	269	341	414
COST OF FACILITIES	0	0	0	0	0	0	0	0	0
TOTAL LOGISTIC SUPPORT COST	9,060	12,172	15,280	21,750	30,172	38,594	9,396	12,485	15,572

*265 AIRCRAFT, 9 BASES, 21,426 FLIGHT HOURS/MONTH

TABLE A-15. SEMR LOGISTIC SUPPORT COST SUMMARY ($K, FY 77)
(Mixed Force Configuration* with BITE to Individual Modules)

COST ELEMENT	THROWAWAY			BASE REPAIR			DEPOT REPAIR		
	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS	10-YEARS	15-YEARS	20-YEARS
COST OF FLU SPARES	11,005	13,136	15,266	3,841	4,869	5,896	8,822	9,850	10,877
COST OF ON-EQUIPMENT MAINTENANCE	1,016	1,523	2,031	1,016	1,523	2,031	1,016	1,523	2,031
COST OF OFF-EQUIPMENT MAINTENANCE	15,436	23,153	30,871	13,931	20,896	27,862	15,685	23,528	31,370
INVENTORY MANAGEMENT COST	9,966	14,935	19,903	132,617	198,900	265,180	10,565	15,821	21,076
COST OF SUPPORT EQUIPMENT	1,545	1,698	1,851	72,857	88,857	104,857	1,864	2,017	2,170
COST OF PERSONNEL TRAINING	181	206	230	443	584	725	191	218	246
COST OF MANAGEMENT AND TECHNICAL DATA	887	1,247	1,607	968	1,329	1,689	968	1,329	1,689
COST OF FACILITIES	0	0	0	0	0	0	0	0	0
TOTAL LOGISTIC SUPPORT COST	40,036	55,898	71,759	225,673	316,958	408,240	39,111	54,286	69,459

*2165 AIRCRAFT, 125 BASES, 93,032 FLIGHT HOURS/MONTH

TABLE A-16. SEMR LOGISTIC SUPPORT COST SUMMARY ($K, FY 77)
(Minimum Cost Cases, BITE to 4-6 Modules, Depot Repair)

COST ELEMENT	C-130/135			MIXED FORCE		
	10 YRS[1]	15 YRS[2]	20 YRS[2]	10 YRS[2]	15 YRS[3]	20 YRS[3]
COST OF FLU SPARES	8,309	9,297	10,475	9,338	10,511	11,874
COST OF ON-EQUIPMENT MAINTENANCE	948	1,423	1,898	1,185	1,777	2,369
COST OF OFF-EQUIPMENT MAINTENANCE	12,304	18,469	24,626	15,534	23,318	31,090
INVENTORY MANAGEMENT COST	9,657	14,495	19,316	10,099	15,165	20,209
COST OF SUPPORT EQUIPMENT	1,413	1,522	1,625	1,561	1,720	1,873
COST OF PERSONNEL TRAINING	165	186	207	176	202	227
COST OF MANAGEMENT & TECH DATA	617	884	1,150	745	1,076	1,406
COST OF FACILITIES	0	0	0	0	0	0
TOTAL LOGISTIC SUPPORT COST	33,413	46,276	59,297	38,638	53,769	69,048

NOTES:
1. SEM TYPES KDE AND MUM REPAIRED.
2. SEM TYPES KDE, MUM, AND UFZ REPAIRED.
3. SEM TYPES KDE, MUM, TPT, AND UFZ REPAIRED.

APPENDIX B
LSC MODEL DATA ELEMENTS

WEAPON SYSTEM VARIABLES

1. EBO - Standard established for expected backorders - the expected number of unfilled demands existing at the lowest echelon (bases) at any point in time. (P)
2. IMC - Initial management cost to introduce a new line item of supply (assembly or piece part) into the Air Force inventory. (S = $50.47/item)
3. M - Number of operating base locations. (P)
4. MRF - Average manhours per failure to complete off-equipment maintenance records. (S = 0.24 hour)
5. MRO - Average manhours per failure to complete on-equipment maintenance records. (S = 0.08 hour)
6. NSYS - Number of systems within the weapon system. (C)
7. OS - Fraction of total force deployed to overseas locations. (P)
8. OSTCON - Average order and shipping time within the CONUS. (S = 0.36 month)
9. OSTOS - Average order and shipping time to overseas locations. (S = 0.53 month)
10. PFFH - Peak force flying hours - expected fleet flying hours for one month during the peak usage period. (P)

Note: (C) = contractor-furnished

(S) = government-furnished standard value (costs in FY-77 dollars)

(P) = government-furnished program-peculiar value

11. PIUP - Operational service life of the weapon system in years. (Program Inventory Usage Period). (P)

12. PMB - Direct productive manhours per man per year at base level (includes "touch time", transportation time, and setup time.) (S = 1500 hours/man/year)

13. PMD - Direct productive manhours per man per year at the depot (includes "touch time", transportation time, and setup time.) (S = 1500 hours/man/year)

14. PSC - Average packing and shipping cost to CONUS locations. (S = $0.64/pound)

15. PSO - Average packing and shipping cost to overseas locations. (S = $1.32/pound)

16. RMC - Recurring management cost to maintain a line item of supply (assembly or piece part) in the wholesale inventory system. (S = $112.85/item/year)

17. SA - Annual base supply line item inventory management cost. (S = $39.63/item)

18. SR - Average manhours per failure to complete supply transaction records. (S = 0.25 hour)

19. TD - Average cost per original page of technical documentation. The average acquisition cost of one page of the reproducible source document (does not include reproduction costs.) (S = $238.26/page)

20. TFFH - Expected total force flying hours over the program inventory usage period. (P)

21. TR - Average manhours per failure to complete transportation transaction forms. (S = 0.16 hour)

22. TRB - Annual turnover rate for base personnel. (S = 0.33)

23. TRD - Annual turnover rate for depot personnel. (S = 0.15)

PROPULSION SYSTEM PECULIAR VARIABLES[1]

1. ARBUT[2] - Engine automatic resupply and buildup time in months. (P)

2. BP[2] - Base engine repair cycle time in months. (P)

3. CMRI[2] - Combined maintenance removal interval - average engine operating hours between removals of the whole engine. (C)

4. CONF - Confidence factor reflecting the probability of satisfying a random demand for a whole engine from serviceable stock to replace a removed engine. (S = 0.90)

5. DP[2] - Depot engine repair cycle time in months. (P)

6. EOH - Average cost per overhaul of the complete engine at the depot expressed as a fraction of the engine unit cost (EUC) including labor and material consumption. Repair and stockage of engine components considered elsewhere as FLUs is not included. (C)

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[1]Not used in SEMR Cost Analysis

[2]Reference AFM 400-1, Volume I, Chapter 7 and Atch 1 for complete description of the Engine Pipeline (Flow Cycle) and use of these terms.

7. ERTS - Return rate for engines. Fraction of removed whole engines which are returned to service by base maintenance. [The complement, (1-ERTS), is the fraction which must be sent to depot for repair/overhaul.] (C)

8. EPA - Number of engines per aircraft. (C)

9. ERMH - Average manhours to remove and replace a whole engine including engine trim and runup time. (C)

10. EUC - Expected unit cost for a whole engine.

11. FC - Fuel cost per unit. (S = $0.423/gallon for JP4; $0.496/gallon for aviation gas)

12. FR - Fuel consumption rate of one engine in units per flying hour. (C)

13. LS - Number of stockage locations for spare engines. (P)

SYSTEM VARIABLES

1. BCA - Total cost of <u>additional</u> items of common base shop support equipment per base required for the system. (C)

2. BAA - Available work time per man in the base shop in manhours per month. (S = 168 hours)

3. BLR - Base labor rate. (S = $14.11/hour)

4. BMR - Base consumable material consumption rate. Includes minor items of supply (nuts, washers, rags, cleaning fluid, etc.) which are consumed during repair of items. (S = $3.48/hour)

5. BPA - Total cost of peculiar base shop support equipment per base required for the system which is not directly related to repair of specific FLUs or when the quantity required is independent of the anticipated workload (such as, overhead cranes and shop fixtures). (C)

6. CS - Cost of software to utilize existing automatic test equipment for the system. (C)

7. DCA - Total cost of additional items of common depot support equipment required for the system. (C)

8. DAA - Available work time per man at the depot in man-hours per month. (S = 168 hours)

9. DLR - Depot labor rate. (S = $19.55/hour)

10 DMR - Same as BMR except refers to depot level maintenance. (S = $5.66/hour)

11. DPA - Same as BPA except relates to depot support equipment. (C)

12. FB - Total cost of new base facilities (including utilities) to be constructed for operation and maintenance of the system, in dollars per base. (C)

13. FD - Total cost of new depot facilities (including utilities) to be constructed for maintenance of the system. (C)

14. FLA - Total cost of peculiar flight-line support equipment and additional items of common flight-line support equipment per base required for the system. (C)

15. H - Number of pages of depot level technical orders and special repair instructions required to maintain the system. (C)

16. IH - Cost of interconnecting hardware to utilize existing automatic test equipment for the system. (C)

17. JJ - Number of pages of organizational and intermediate level technical orders required to maintain the system. (C)

18. N - Number of different FLUs within the system. (C)

19. SMH - Average manhours to perform a scheduled periodic or phased inspection on the system. (C)

20. SMI - Flying hour interval between scheduled periodic or phased inspections on the system. (C).

21. SYSNOUN - Name of the system - up to 60 alphanumeric characters. (C)

22. TCB - Cost of peculiar training per man at base level including instruction and training materials. (C)

23. TCD - Cost of peculiar training per man at the depot including instruction and training materials. (C)

24. TE - Cost of peculiar training equipment required for the system. (C)

25. XSYS - System identification. The assigned five-character alphanumeric Work Unit Code of the system. (C)

FLU VARIABLES

1. BCMH - Average manhours to perform a shop bench check, screening, and fault verification on a removed FLU prior to initiating repair action or condemning the item. (C)

2. BMC - Average cost per failure for an FLU repaired at base level for stockage and repair of lower level assemblies expressed as a fraction of the FLU unit cost (UC). This is the implicit repair disposition cost for an FLU representing labor, material consumption, and stockage of lower indenture components within the FLU (e.g., shop replaceable units or modules). (C)

3. BMH - Average manhours to perform intermediate-level (base shop) maintenance on a removed FLU including fault isolation, repair, and verification. (C)

4. BRCT - Average base repair cycle time in months. The elapsed time for an RTS item from removal of the failed item until it is returned to base serviceable stock. (S = 0.13 month)

5. COND - Fraction of removed FLUs expected to result in condemnation at base level. (C)

6. DMC - Same as BMC except refers to depot repair actions. (C)

7. DMH - Same as BMH except refers to depot-level maintenance.

8. DRCT - Average depot repair cycle time in months. The elapsed time for an NRTS item from removal of the failed item until it is made available to depot serviceable stock. (S = 1.84 months for organic repair; 2.25 months for contract repair)

9. FLUNOUN - Word description or name of the FLU - up to 60 alphanumeric characters. (C)

10. IMH - Average manhours to perform corrective maintenance of the FLU in place or on line including fault isolation, repair, and verification. (C)

11. K - Number of line items of peculiar shop support equipment used in repair of the FLU. (C)

12. MTBF - Mean time between failures in operating hours of the FLU in the operational environment. (C)

13. NRTS - Fraction of removed FLUs expected to be returned to the depot for repair. (C)

14. PA - Number of new P coded reparable assemblies within the FLU. (C)

15. PAMH - Average manhours expended in place on the complete system for preparation and access for the FLU; for example, jacking, unbuttoning, removal of other units and hookup of support equipment. (C)

16. PP - Number of new P coded consumable items within the FLU. (C)

17. QPA - Quantity of like FLUs within the parent system. (quantity per application) (C)

18. RIP - Fraction of FLU failures which can be repaired in place or on line. (C)

19. RMH - Average manhours to fault isolate, remove, and replace the FLU and verify restoration of the system to operational status. (C)

20. RTS - Fraction of removed FLUs expected to be repaired at base level. (C)

21. SP - Number of standard (already stock-numbered) parts within the FLU which will be managed for the first time at bases where this system is deployed. (C)

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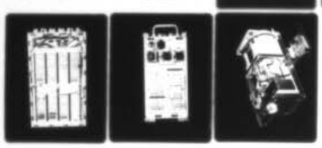

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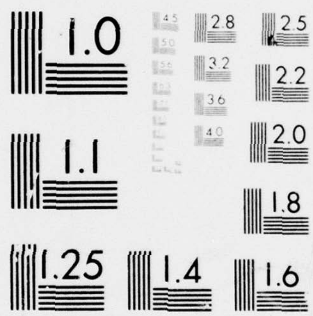

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22. UC - Expected unit cost of the FLU at the time of initial provisioning. (C)

23. UF - Ratio of operating hours to flying hours for the FLU. (Use Factor) (C)

24. W - FLU unit weight in pounds. (C)

25. XFLU - FLU identification. The assigned five-character alphanumeric Work Unit Code of the FLU. (C)

SUPPORT EQUIPMENT VARIABLES

1. BUR - Combined utilization rate for all like items of support equipment - base level. (C)

2. CAB - Cost per unit of peculiar support equipment for the base shop. (C)

3. CAD - Same as CAB except refers to depot support equipment. (C)

4. COB - Annual cost to operate and maintain a unit of support equipment at base level expressed as a fraction of the unit cost (CAB). (C)

5. COD - Same as COB except refers to depot support equipment. (C)

6. DOWN - Fraction of downtime for a unit of support equipment for maintenance and calibration requirements. (C)

7. DUR - Same as BUR except refers to depot support equipment. (C)

8. XSE - SE identification - up to 20 alphanumeric characters. (C)

APPENDIX C
LSC MODEL EQUATIONS

C_1 = COST OF FLU SPARES

$$= M \sum_{i=1}^{N} (STK_i)(UC_i)$$

$$+ \sum_{i=1}^{N} \frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)(NRTS_i)(DRCT_i)}{MTBF_i}(UC_i)$$

$$+ \sum_{i=1}^{N} \frac{(TFFH)(QPA_i)(UF_i)(1-RIP_i)(COND_i)}{MTBF_i}(UC_i) \qquad (C.1)$$

The first two terms in C_1 are the cost to fill the base and depot repair pipelines, respectively. The quantities computed are those required to support the peak level of program activity. The third term is the cost to replace failed FLUs which will be condemned at base level over the life of the system.

In the first term, STK_i represents the number of spares of the i^{th} FLU required for each base to fill the base repair pipeline including a safety stock to protect against random fluctuations in demand. The computation of STK_i considers the mean demand rate per base,

$$\lambda_i = \frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)}{(M)(MTBF_i)} \qquad (C.2)$$

the weighted pipeline time

$$t_i = (RTS_i)(BRCT_i) + (NRTS_i)\ [(OSTCON)(1-OS) + (OSTOS)(OS)] \qquad (C.3)$$

and EBO, the established standard for expected backorders for the weapon system. Therefore, the product, $\lambda_i t_i$, represents the expected number of demands on supply for the i^{th} FLU over

its average base repair pipeline time. Then, find the minimum value of STK_i such that

$$\sum_{x > STK_i} (x - STK_i)\, p(x \mid \lambda_i t_i) \leq EBO \tag{C.4}$$

where the distribution of probabilities of demand given a mean demand,

$$p(x \mid \lambda_i t_i) \tag{C.5}$$

is Poisson. Therefore, the cost to provide base repair pipeline spares of the i^{th} FLU for all bases is

$$(M)(STK_i)(UC_i) \tag{C.6}$$

C_2 = ON-EQUIPMENT MAINTENANCE

$$\begin{aligned} &= \sum_{i=1}^{N} \frac{(TFFH)(QPA_i)(UF_i)}{MTBF_i} [PAMH_i + (RIP_i)(IMH_i) \\ &\quad + (1-RIP_i)(RMH_i)]\ (BLR) + \frac{TFFH}{SMI}\ (SMH)\ (BLR) \\ &\quad + \boxed{\frac{(TFFH)(EPA)}{CMRI}\ (ERMH)(BLR)} \end{aligned} \tag{C.7}$$

The first term in C_2 is the labor manhour cost to perform on-equipment (flight line) maintenance on FLUs due to (unscheduled) failures over the life of the system. The element,

$$PAMH_i + (RIP_i)(IMH_i) + (1-RIP_i)(RMH_i) \tag{C.8}$$

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is the weighted average on-equipment maintenance manhours per failure of the i^{th} FLU including Preparation and Access Time and either in-place repair or removal and replacement as appropriate.

The second term is the labor manhour cost to perform scheduled maintenance on the complete system over the life cycle.

The third term is applicable only when dealing with a propulsion or powerplant system. It is the maintenance manhour cost to remove and replace whole engines on the aircraft.

C_3 = OFF-EQUIPMENT MAINTENANCE

$$
\begin{aligned}
= \sum_{i=1}^{N} \frac{(TFFH)(QPA_i)(UF_i)(1-RIP_i)}{MTBF_i} \Bigg\{ & (BCMH_i)(BLR) \\
& + RTS_i \; [(BMH_i)(BLR + BMR) + (BMC_i)(UC_i)] \\
& + NRTS_i \; [(DMH_i)(DLR + DMR) + (DMC_i)(UC_i)] \\
& + [2(NRTS_i) + COND_i][(PSC)(1-OS) + (PSO)(OS)](1.35\ W_i) \Bigg\} \\
& + \boxed{\frac{(TFFH)(EPA)(1-ERTS)}{CMRI}(EOH)(EUC)} \qquad (C.9)
\end{aligned}
$$

The first term in C_3 is the labor manhour and material cost to perform off-equipment maintenance on failed, removed FLUs in base or depot repair facilities. All failed FLUs are first bench-checked to verify failure and then either repaired in the base intermediate maintenance shop (RTS), returned to the depot for repair (NRTS) or condemned (COND). The cost of failure verification results from expending manhours (BCMH). The cost to repair an item results from direct repair manhours (BMH or DMH) and the implied repair disposition cost to stock

and repair lower indenture components and assemblies (BMC or DMC). Included is the transportation cost for NRTS FLUs and condemnation replacements. The 1.35 factor is the ratio of packed to unpacked weight. The second term is applicable only when dealing with a propulsion or powerplant system. It is the implied cost to perform overhaul of a complete engine at the depot including labor and material consumption. It does not include, however, repair and stockage of engine components considered elsewhere as FLUs.

C_4 = INVENTORY MANAGEMENT COST

$$= [\mathrm{IMC} + (\mathrm{PIUP})(\mathrm{RMS})] \sum_{i=1}^{N} (\mathrm{PA}_i + \mathrm{PP}_i + 1)$$

$$+ (\mathrm{M})(\mathrm{SA})(\mathrm{PIUP}) \sum_{i=1}^{N} (\mathrm{PA}_i + \mathrm{PP}_i + \mathrm{SP}_i + 1) \quad \text{(C.10)}$$

The first term in C_4 is the cost to enter new line items of supply into the government inventory and to manage them over the life of the system.

The second term is the life cycle base level supply management cost of these new items of supply as well as common, already-stock-numbered items which will be carried for the first time in base supply where this system is deployed.

C_5 = COST OF SUPPORT EQUIPMENT

$$= \sum_{i=1}^{N} \frac{(\mathrm{PFFH})(\mathrm{QPA}_i)(\mathrm{UF}_i)(1-\mathrm{RIP}_i)}{\mathrm{MTBF}_i}$$

$$\sum_{j=1}^{K} \left\{ \frac{(\mathrm{RTS}_i)(\mathrm{BMH}_i + \mathrm{BCMH}_i)}{(\mathrm{BUR}_j)(\mathrm{BAA})(1-\mathrm{DOWN}_j)} [1 + (\mathrm{PIUP})(\mathrm{COB}_j)]\mathrm{CAB}_j \right.$$

$$\left. + \frac{(\mathrm{NRTS}_i)(\mathrm{DMH}_i)}{(\mathrm{DUR}_j)(\mathrm{DAA})(1-\mathrm{DOWN}_j)} [1 + (\mathrm{PIUP})(\mathrm{COD}_j)]\mathrm{CAD}_j \right\}$$

$$+ \left\{ [1 + 0.1(\mathrm{PIUP})][\mathrm{DCA}+\mathrm{DPA}+\mathrm{M}(\mathrm{BCA}+\mathrm{BPA}+\mathrm{FLA})] + \mathrm{CS} + \mathrm{IH} \right\}$$

(C.11)

The first term in C_5 computes the quantities and costs to acquire and maintain new, peculiar items of depot and base shop support equipment (SE) utilized in repair of FLUs. The quantities are derived by considering the anticipated repair workload, the servicing capability of the shops and certain characteristics of the SE.

From queuing theory, we are given

$$\rho = \frac{\lambda}{n\mu} \leq 1 \qquad \text{(C.12)}$$

where λ is the workload arrival rate, μ is the service rate of one server, n is the number of servers and ρ is the combined utilization rate of the servers which must be not greater than unity. Our objective is to calculate the minimum number of pieces of each item of support equipment ("servers") necessary to support the anticipated workload. Therefore, we must rearrange terms in (C.12):

$$n = \frac{\lambda}{\rho\,\mu} \qquad \text{(C.13)}$$

For our purposes, the arrival rate of workload in the base shop for the i^{th} FLU is given by

$$\lambda = \frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)(RTS_i)}{MTBF_i} \qquad \text{(C.14)}$$

The service rate for one unit of the j^{th} item of SE in support of the i^{th} FLU is given by

$$\mu = \frac{(BAA)(1-DOWN_j)}{(BMH_i + BCMH_i)} \qquad \text{(C.15)}$$

And the combined utilization rate, ρ, is given by the variable BUR. Therefore, by combining terms, the quantity

$$\frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)(RTS_i)(BMH_i + BCMH_i)}{(MTBF_i)(BUR_j)(BAA)(1-DOWN_j)} \qquad (C.16)$$

represents the fractional requirement for the j^{th} item of SE to support the i^{th} FLU. In order to compute SE costs realistically, integer quantities should be considered. All fractional requirements for SE item j should be accumulated for all FLUs in the weapon system and the result rounded up to a whole number divisible by M to give the total base-level requirement for SE item j.

A similar discussion applies to the computation of depot SE. Using (C.13) again, the depot parameters are

$$\lambda = \frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)(NRTS_i)}{MTBF_i} \qquad (C.17)$$

$$\mu = \frac{(DAA)(1-DOWN_j)}{DMH_i} \qquad (C.18)$$

$$\rho = DUR \qquad (C.19)$$

The fractional requirement for the j^{th} item of SE to support the i^{th} FLU is represented by

$$\frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)(NRTS_i)(DMH_i)}{(MTBF_i)(DUR_j)(DAA)(1-DOWN_j)} \qquad (C.20)$$

which should be integerized to give the depot-level requirement for SE item j.

The second term in C_5 is cost to acquire and maintain items of peculiar SE which are not directly workload related and items of common SE which must be procured in additional quantities. The arbitrary value of 0.1 is the analog of COB or COD used in the first term.

C_6 = COST OF PERSONNEL TRAINING

$$= \frac{[1 + (PIUP-1)(TRB)]TCB}{(PIUP)(PMB)} \left[\sum_{i=1}^{N} \frac{(TFFH)(QPA_i)(UF_i)}{MTBF_i} \right.$$

$$\left\{ PAMH_i + (RIP_i)(IMH_i) + (1-RIP_i)[RMH_i + BCMH_i + \right.$$

$$\left. + (RTS_i)(BMH_i)] \right\} + \frac{TFFH}{SMI}(SMH) + \left. \boxed{\frac{(TFFH)(EPA)}{CMRI}(ERMH)} \right]$$

$$+ \frac{[1 + (PIUP-1)\ (TRD)]\ TCD}{(PIUP)(PMD)}$$

$$\sum_{i=1}^{N} \frac{(TFFH)(QPA_i)(UF_i)}{MTBF_i} (1-RIP_i)(NRTS_i)(DMH_i) + TE \tag{C.21}$$

The first and second terms in C_6 are the costs to train maintenance personnel for bases and the depot respectively. Using the second term to simplify the explanation, the quantity

$$\frac{(TFFH)(QPA_i)(UF_i)(1-RIP_i)(NRTS_i)(DMH_i)}{MTBF_i} \tag{C.22}$$

gives the total depot labor manhour requirement for the i^{th} FLU over the life of the system. Dividing (C.22) by the quantity

$$(PIUP)(PMD) \tag{C.23}$$

gives the workload-related personnel equivalents required at the depot to support the i^{th} FLU. Multiplying by the quantity

$$1 + (PIUP-1)(TRD) \qquad (C.24)$$

reflects the turnover of personnel and essentially gives the total training requirement over the life of the system which is then multiplied by the cost to train one man, TCD. A similar exercise applies to the computation of base-level training requirements in the first term. Note that the last quantity within the first term is applicable only when dealing with a propulsion system.

C_7 = COST OF MANAGEMENT AND TECHNICAL DATA

$$= \sum_{i=1}^{N} \frac{(TFFH)(QPA_i)(UF_i)}{MTBF_i} [MRO + (1-RIP_i)(MRF + SR + TR)] BLR + \frac{TFFH}{SMI} [MRO + 0.1 (SR + TR)] BLR + TD(JJ + H) \qquad (C.25)$$

The first term in C_7 is the maintenance labor cost associated with equipment failures to complete the required on- and off-equipment maintenance forms, supply transaction records and transportation forms. The second term is the similar cost associated with scheduled or periodic maintenance. The third term is the cost to acquire Technical Orders, overhaul manuals, and other special technical documentation or repair instructions.

C_8 = COST OF FACILITIES

$$= FD + (M)(FB) \tag{C.26}$$

This equation gives the cost of new, special base and depot real facilities (including utilities) necessary for operation and maintenance of the system.

C_9 = COST OF FUEL CONSUMPTION

$$= (TFFH)(EPA)(FR)(FC) \tag{C.27}$$

This equation gives the life cycle fuel cost for those weapon systems having propulsion systems.

C_{10} = COST OF SPARE ENGINES

$$= [(LS)(X) + Y]\ EUC \tag{C.28}$$

In C_{10}, X is the number of whole spare engines required to fill the base-level portion of the engine pipeline including both the base repair cycle and the automatic resupply and buildup time. Y is the number of engines required to fill the depot overhaul cycle. Both X and Y include a safety level stock to protect against pipeline shortages due to abnormal or unpredictable demand conditions. The computation of X considers the mean demand rate,

$$\frac{(PFFH)(EPA)}{(LS)(CMRI)} \tag{C.29}$$

the weighted base pipeline time,

$$(ERTS)(BP) + (1-ERTS)(ARBUT) \tag{C.30}$$

and CONF, the established confidence level factor expressed in terms of off-the-shelf availability. The product of the demand rate and the weighted pipeline time gives the argument

(ARGB) of the following equation. The desired value of X is the minimum value such that

$$\sum_{n=0}^{X} \frac{(e^{-ARGB})(ARGB)^n}{n!} \geq CONF \qquad (C.31)$$

A similar computation applies for Y where the mean demand rate is

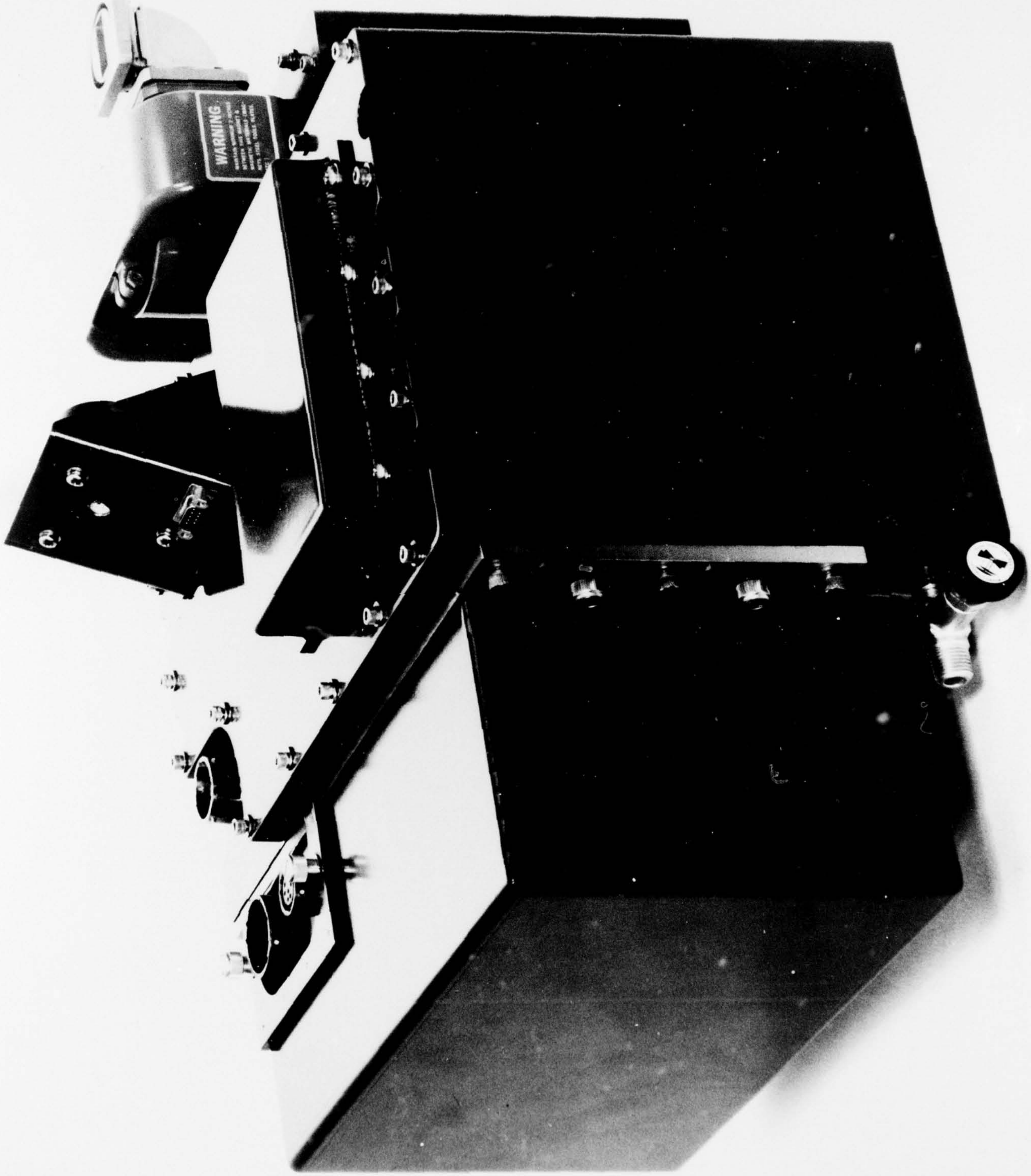
$$\frac{(PFFH)(EPA)}{CMRI} \qquad (C.32)$$

and the weighted pipeline time is

$$(1-ERTS)(DP) \qquad (C.33)$$

The product of these two terms gives the argument (ARGD) of the following equation. The desired value of Y is the minimum value such that

$$\sum_{n=0}^{Y} \frac{(e^{-ARGD)})(ARGD)^n}{n!} \geq CONF \qquad (C.34)$$



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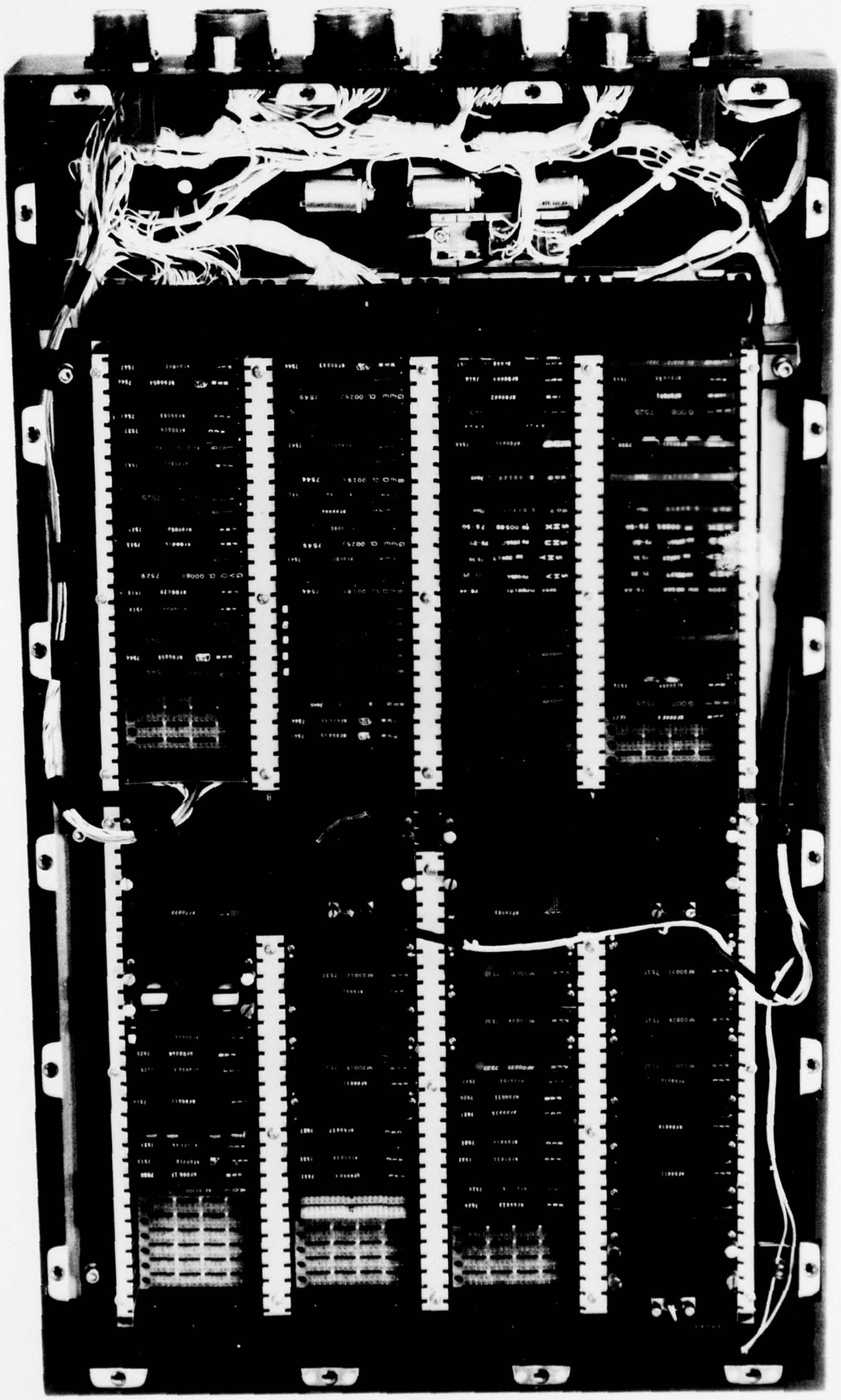

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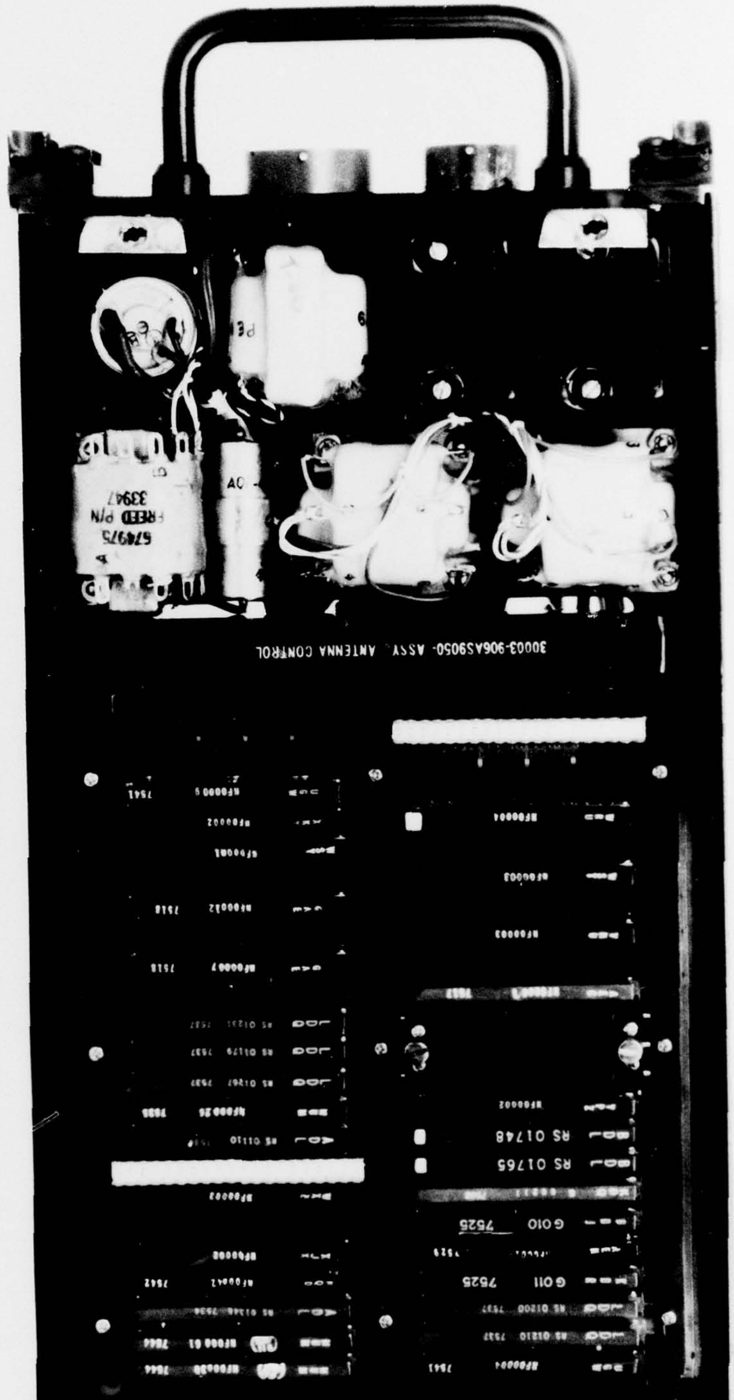
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